Using Cognitive Cues to Facilitate Selective Stopping of Planned Actions:

A Behavioural and Physiological Approach

Elise Yaxley

A report submitted as a partial requirement for the degree of Bachelor of Psychological Science with Honours in Psychology at the University of Tasmania, 2018.

Statement of Sources

I declare that this report is my own original work and that contributions from others have been duly acknowledged.

. . . .

Elise Yaxley   Date

Acknowledgements

Most importantly, thank you to my honours supervisor, Mark Hinder. Without your support and guidance, and the many emails you replied to of mine, I would not have been able to get this far.

Thank you to Tess Nikitenko for your assistance and support, and especially for making it such an enjoyable, funny experience. And thank you to Rohan Puri also for your assistance throughout this process.

Thank you to my fellow honours students for making our honours year a memorable one.

Lastly, thank you to my family and friends for loving and supporting me even when I was stressed and grumpy. And for still managing to proof read many of my assignments and thesis.

Table of Contents

List of Figures

Using Cognitive Cues to Facilitate Selective Stopping of Planned Actions:

A Behavioural and Physiological Approach

Elise Yaxley

Word Count: 10,190

Abstract

Inhibitory control is the ability to cancel movements in response to changes in the environment (Band, Van Der Molen & Logan, 2003). The current study used behavioural and physiological measures to investigate selective inhibitory motor control, specifically whether prior cognitive knowledge, the type of prior knowledge presented, and hand dominance influenced stopping performance. Thirty-six participants aged between 18 to 36 years (M=24, SD=5.25) participated in a stop signal task, whereby they responded to visual 'go' signals with a bimanual button press and had to cancel (inhibit) one of the button presses on a small proportion of trials while continuing to execute the contralateral press. Electromyography (EMG) analysis was used to determine whether low levels of muscle activity were present on a correctly inhibited response (covert response). Behaviorally, prior cognitive knowledge reduced reaction time costs associated with selective stopping but did not abolish them. However, the type of knowledge presented, and hand dominance did not significantly reduce selective stop costs and stop signal reaction times. The EMG analysis suggests that the type of knowledge presented can impact inhibitory control, specifically depending on an individual's hand dominance. These findings build on previous research suggesting that prior cognitive knowledge can improve selective stopping abilities.

Throughout our daily lives we face situations where it is necessary to change a planned movement in response to an environmental demand, such as having to put the brakes on in your car because another car has pulled out in front of you, or changing your gait pattern when playing a sport so you can avoid being tackled by another player (Band, Van Der Molen & Logan, 2003; Coxon, Stinear & Byblow, 2007). It is the inhibitory motor control pathways within the brain that allow the human body to cancel a whole, or part of a movement (MacDonald, McMorland, Stinear, Coxon & Byblow, 2017). These motor pathways take input from cognitive centres within the brain to determine the appropriate response and further, update the behavioural response when changes are required (e.g., on the basis of updated sensory or cognitive input).

Inhibitory control is a particularly important area of research as individuals with health conditions such as Tourette's syndrome (Verbruggen & Logan, 2008), attention deficit hyperactive disorder (Schachar, Mota, Logan, Tannock & Klim, 2000), and even healthy aging (Fujiyama, Hinder, Schmidt, Garry & Summers, 2012), find inhibiting behaviours difficult as their condition often restricts their ability to use cognitive functions and sensory information to change their movements in relation to environmental demands. Because of their impairment to appropriately change their behaviours in relation to environmental changes, these individuals are at risk of potentially causing harm to themselves and/or others. Therefore, it is important to further our understanding of the mechanisms of inhibitory motor control, in order to improve the treatment and interventions that are used to assist individuals with health conditions that negatively impact their movement abilities.

The current research focused on inhibitory motor control in relation to selectively stopping particular components of a prepared bimanual (multi-component) movement. A modified stop signal task was used to test these stopping behaviours and assess how cognitive cues could potentially facilitate efficient inhibitory control performance. The following section of this thesis reviews and evaluates the relevant literature of inhibitory motor control, specifically selective stopping, as well as the mechanisms that are believed to be involved in the stopping process. Additionally, a summary of the behavioral measures, the horse race model, and the physiological measures, i.e., electromyography (EMG) will be explored, together with an overview of the aims and hypotheses of the current study.

Inhibitory Control

There are two main categories of inhibitory control; global and selective. Global inhibition involves cancelation of all components of a prepared movement, whereas selective inhibition involves one component of a complex, or multi component movement being stopped while the other component continues to be performed (Duque, Greenhouse, Labruna & Ivry, 2017). Global inhibition is the process of stopping all movements, both prepared and other potential movements; such as stopping your walking pattern, so you do not walk in front of an oncoming car. In terms of the motor inhibition, when individuals complete a task with no knowledge of what movement they will have to inhibit, once directed to stop, it is suggested that the motor command is globally inhibited, and a new alternative response is re-initiated if required (Coxon, Stinear & Byblow, 2006).

Although global stopping has been widely researched in laboratories, it is rarely prominent in everyday situations, as it is often necessary to continue a component of a behaviour while requiring to stop another component (Aron & Verbruggen, 2008). Selective stopping is the process of inhibiting one component of a movement while continuing to execute the other components of the movement, for example, if you are walking across the road whilst searching through your bag to find an item and a car pulls out in front of you, you will stop walking but continue to search through your bag until it is safe for you to start walking across the road again. Selective stopping is a more appropriate mechanism to use in everyday life when needing to inhibit behaviours.

There are several hypotheses that have been postulated to explain the process of selective inhibition. Initially, De Jong, Coles and Logan (1995) suggested that selective stopping occurred due to a two-part process. Firstly, a peripheral mechanism delays the response until it is obvious that stopping is necessary. From there, a cortical mechanism triggers a selective stop for a specific behaviour. However, further research suggests that De Jong et al.'s hypothesis may not be an accurate representation of the underlying selective stopping process. In comparison, the restart model suggests that selective stopping occurs in a two-part sequential process (Coxon, Stinear & Byblow, 2007). The basal ganglia initiates a global 'brake' of all prepared movement when a stopping response is required, and further re-programming is required in order to perform the nonaborted unimanual behaviour.

Neuroimaging research has found that the right inferior frontal cortex of the prefrontal cortex and the basal ganglia are critical brain regions within the inhibitory control network (Coxon et al., 2006). These regions make up the fronto-basal-ganglia circuit, that are transmitted via a hyperdirect pathway (Verbruggen & Logan, 2008). The hyperdirect pathway is one of the few pathways that is active during a stop signal response, specifically a global stop (Duque et al., 2017). This pathway allows for fast inhibition of movement, as the subthalamic nucleas (STN) sends excitatory signals to the globus pallidus, which further sends inhibitory signals to the thalamus, thus, globally suppressing all motor commands. These regions converge on the motor cortex (M1), which initiates movement and integrates a range of inputs from other regions within the brain. When a stopping response has been sent to M1, the prefrontal cortex has a top-down influence, with a goal to inhibit the motor command. Coxon et al. (2006) suggest that when a motor command is successfully inhibited, GABAenrgic inhibitory networks within M1 increase in activation, thus, suggesting that multiple pathways within the brain have a combined effect on inhibiting motor commands.

The hyperdirect pathway previously explained, allows us to understand the global mechanisms of inhibiting responses. The signals received from the STN stop all movements initiated from M1, thus, leading to the term global inhibition (Gillies & Willshaw, 1998). In contrast, Aron and Verbruggen (2008) suggest that selective stopping is processes through an indirect, fronto-striatal–pallidal–subtha- lamic pathway. The indirect pathway has more synapses compared to the hyperdirect pathway, thus, resulting in slower reaction times (i.e., in response to the stop command) but more precise (or selective) tendencies in terms of the nature of the inhibition. As a consequence of using this pathway individuals make a trade-off where accuracy outweighs speed (Duque et al., 2017). Whereas, if speed (i.e., quickly being able to successfully inhibit any action) is the primary goal, individuals will initiate a global stop and subsequently re-initiate a new alternative response.

Stop Signal Task

In the laboratory, inhibitory motor control is commonly investigated using the stop-signal paradigm, where participants are required to inhibit a planned movement (Lappin & Eriksen, 1966). Lappin and Erikson's original variant of the task requires participants to make a button press with their finger when a go signal is presented on a screen (e.g. a green dot, an arrow). On a minority of trials (~30%), a stop signal is presented (e.g. a red dot, a cross), prompting participants to inhibit their planned movement, or their go response. This original variant of the task taps into global stopping, to clarify, that is the stopping of a whole component of a movement (Aron & Verbruggen, 2008).

In real life however, humans often only need to stop one component of a movement while still continuing to perform the other components; this is known as selective inhibition or selective stopping. Lappin and Erikson's (1966) original variant of the task did not allow investigation of selective stopping. Accordingly, Coxon et al. (2007) generated a variant of the task in order to test this, in which participants were instructed to bimanually respond to two vertically oriented indicators using two buttons on a mouse pad. The indicators moved vertically up towards a horizontal line and participants were instructed to release the buttons as close to the horizontal line as possible. On a proportion of trials, the vertical lines would disappear, and participants were instructed to not release the buttons if this occurred. This was the stopping or inhibiting component of the task.

The hyperdirect pathway previously explained, allows us to understand the global mechanisms of inhibiting responses. The signals received from the STN globally suppress all movements initiated from M1 (Aron & Verbruggen, 2008). In terms of the stop-signal paradigm, evidence suggests that when individuals complete a task with no prior knowledge as to what movement they will have to inhibit, once told to stop, all motor commands are globally inhibited via the hyperdirect pathway, and a new alternative command is re-initiated (Coxon et al., 2006).

In contrast, Aron and Verbruggen (2008) suggest that prior cognitive knowledge, informing individuals as to which component of the stop signal they have to inhibit, could result in a more selective stop mechanism being activated. As a result, participants will correctly stop one hand while continuing to make a button press with the other hand with little or no delay. They introduced an additional condition to the stop signal task where participants were presented with a cue before the go signal, either ‘maybe stop left’ or ‘maybe stop right’. The cues indicated to participants that if the trial is a stop trial, then they will be required to stop the corresponding hand, while continuing to make a button press with the other hand. It is suggested that foreknowledge produces a rule in the participant’s working memory, which they use to make a plan to potentially stop a behaviour (Claffey, Sheldon, Stinear, Verbruggen & Aron, 2010). This plan allows the participant to make a selective stop, compared to globally stopping all behavioural movements and re-initiating a unimanual response, as they are already anticipating to stop one component of the behaviour.

Research suggests that foreknowledge permits the indirect pathway to be activated, thus, resulting in a selective stop rather than a global stop (Cai, Oldenkamp & Aron, 2011). Although, the foreknowledge condition produces a more selective stop using the indirect pathway, it also produces a slower reaction time. It is believed that this slower reaction time is a result of the indirect pathway and its increased number of synapses. However, by providing participants with prior knowledge, the delay in response time associated with selective stopping in the non-stopping hand is reduced, this is known as the selective stop cost (SSC).

The current research extends previously reviewed papers by manipulating the manner in which the cue is presented. Human communication originated through gestures and symbols, and then evolved into written language (Fay, Lister, Ellison & Goldin-Meadow, 2014). It is therefore a natural habit for humans to process symbols efficiently and for symbols to underpin our ability to produce and interpret written language. However, in majority of stop signal tasks the cue is presented in words, such as ‘maybe stop XXX’ (Aron & Verbruggen, 2008; Cai et al., 2011; Claffey et al., 2010). The current study introduced a between-subjects manipulation where the cue was presented in word form to half the participants and symbol form to the other half of the participants. As the ‘go’ and ‘stop’ stimuli are presented in symbol form (green and red arrows) it was proposed that the cue be presented in symbol form so that it matched the stimuli, thus, making the cue more salient to the task.

Horse Race Model

Logan and Cowan’s (1984) horse race model is commonly used as a psychological framework to explain inhibitory control, as it is suggested that it reflects empirical data accurately. Their model explains inhibitory control to be like a horse race; the horses are the evidence for a go response, also referred to as the imperative signal (IS), and evidence for inhibiting a planned action in response to the stop signal (SS). These horses' race towards a finish line defined as a threshold, which needs to be met before the response is initiated (go wins the race) or cancelled (stops wins the race). The evidence for the IS starts the race first as the IS is always presented before the SS, with accumulation for the stopping process beginning at a delay following the IS (i.e., upon presentation of the SS). The observable behavioral response is determined by which 'accumulator' reaches the threshold first; if the IS accumulator reaches the threshold first an observable behavioral response will occur. Whereas, if the SS accumulator reaches the threshold first no response will be observed, and it can be presumed that the behavior has been correctly inhibited.

The horse race model can be used as an estimate for reaction times that are used to analyse behavioral data on the stop signal task, such as the stop signal delay (SSD), go reaction time (Go RT) and stop signal reaction time (SSRT) (Verbruggen & Logan, 2008). The SSD is the time between the onset of the IS and the SS. If SSD increases, the onset of the SS will increase, thus, resulting in the stop response (i.e., correct inhibition) occurring less frequently as it will be more difficult to stop. To clarify, if the delay between the IS and the SS is longer, it is harder for a stop response to occur, and it can be presumed that the individual has good inhibitory control. Whereas, if the delay between the IS and the SS is shorter, it is more likely for a stop response to occur as it is easier. Go RT is the average response time on go trials, from the onset of the IS till the time the behavioural response is made. Finally, SSRT is calculated as the difference between RT and SSD (mean method), but is only true when the stop success algorithm is at 50%, for intances when stop success is not 50%, another algorithm is required to accurately estimated SSRT (see Verbruggen & Logan, 2009). SSRT is the most common measurement of inhibitory control, but it cannot be measured directly like go RT and SSD, rather it is estimated by subtracting SSD from the go

RT (Verbruggen & Logan, 2009). SSRT can be used to estimate how long it will take for a stop response to be aborted.

Electromyography

Electromyography (EMG) is a non-invasive technique involving placing surface electrodes on the skin over a muscle to record the electrical activity of the underlying muscle. In the context of stop signal paradigm, EMG can be used to analyse the underlying inhibitory control processes that cannot be determined from considering the behavioural responses alone. Specifically, electrical activity will be apparent in a muscle when a motor command is initiated to facilitate a behavioural response (e.g., a button press). When a stop signal is presented the overt response may be successfully stopped, but a covert response may still be observed in the muscle activity (Coxon et al., 2006). This 'partial' response is not sufficient to result in a button press, but, can be used as evidence of initiation and subsequent cancellation of the planned motor movement (De Jong, Coles, Logan & Gratton, 1990).

Research utilising EMG in the field of inhibitory control has challenged the existing notion that there is a point of no return, that is, there are only two options in the inhibitory process, going or stopping. McGarry and Franks' (1997) research suggested that inhibition can occur at the end of the inhibitory control process within the brain, whereby individuals display covert muscle activation, as if they had initiated a response but not overtly performed it. They suggest that these partial responses challenge the notion that muscle activity only occurs once a motor command has been made (Logan & Cowan, 1984).

In comparison, Servant, White, Montagnini & Burle (2015), suggest that partial responses occur within a two-point threshold model. The first threshold accumulates enough evidence to initiate M1 to send a motor command, and when evidence reaches the second threshold, there is no point of return for inhibiting that motor response. Accordingly, this technique allows us to measure a correctly inhibited behaviour in the form of a covert muscle response, and to what extent that response was initiated using a global or selective mechanism.

Handedness

Handedness, or the preferred dominance of one hand over another for the undertaking of manual tasks, is an additional aspect that could influence inhibitory control, and more specifically the stop signal paradigm. As the interpretation of results from the stop signal tasks are premised upon participant's reaction times of hand movements, a participant's handedness could produce unconscious differences in stopping behaviours for dominant versus non-dominant limbs. Shen and Franz (2005) suggest that the dominant hand is approximately 6ms faster than the non-dominant hand in performing both bimanual and unimanual tasks. It has been shown that non-dominant/dominant hand differences in reaction time tasks have been observed, and we anticipate that hand effect might also be observed in the response to stopping behaviours (Garry & Franks, 2000).

However, more critically for the current research is that the action of the non-dominant hand is often more closely coupled to the action of the dominant hand, in bimanual tasks (MacDonald, Stinear & Byblow, 2012). More specifically, research suggests that the motor cortex may have strong temporal and spatial constraints on bimanual movements, resulting in the coupling of hands, rather than initiating separate movements and executing them at the same time (Ko & Miller, 2011; Summers, Davis & Byblow, 2002). For example, drummers initially find it challenging to separate the movements of their arms to make individual arm movements resulting in different sounds (Summers, Krampe, Engbert & Kliegl, 2002). If one component of the movement is different for one side of the body compared to the other, a global stop is initiated, and a neural uncoupling process needs to occur before the separate movements of the coupled body parts are re-initiated. Specifically, the non-dominant hand may have more difficulty in uncoupling its response from the dominant hand, and thus, exhibit more difficulty in independent actions (e.g., stopping the non-dominant hand). It is this coupling that might result in between-hand differences in stopping tasks that require one hand to inhibit its response, while the other hand continues to execute its response.

However, Bäumer and colleagues (2007) suggest that the interhemispheric inhibitory drive from the dominant hemisphere (to the non-dominant hemisphere) is stronger than the inhibitory drive from the non-dominant hemisphere (to the dominant hemisphere). Therefore, they suggest that for a right-hand dominant individual the non-dominant hand (left hand) will be inhibited more during a right-hand movement than the dominant hand (right hand) is during a left-hand movement, thus, this might suggest that the non-dominant hand is less tightly coupled to the dominant hand. In contrast to the findings of Shen and Franz (2005) which suggest that the dominant hand is better at inhibiting movements, Bäumer et al., (2007) suggests that inhibition of the non-dominant hand is stronger.

MacDonald and colleagues (2012) electromyography (EMG) data suggests that on selective stop trials, partial bursts occurred in both hands before a movement burst occurred. As alluded to previously, partial or covert bursts are behaviorally unobservable muscle bursts in the responding muscle that do result in observable responses (i.e., responses that do not produce enough force to depress a button). They suggest that the partial bursts in each hand represent the coupling of the movements, and are followed by an un-coupling, global stopping process where both the hands are stopped and a more appropriate selective behavioral competent is executed. The non-dominant body part mimics the dominant body part, with research suggesting that there is a small delay of movement initiation of the non-dominant body part (Byblow, Lewis, Stinear, Austin & Lynch, 2000). Research on asymmetrical movements and circle drawing, suggests that the dominant hand will produce more precise circles, whereas the non-dominant hand produces distorted circles, further supporting that the dominant hand is more precise and more prominent than the non-dominant hand (Carson, Thomas, Summers, Walters & Semjen, 1997).

This leads us to question whether the stop signal task is influenced by handedness and coupling effects. Therefore, we propose that in the current research, if coupling of the bimanual button presses was occurring, we would expect that the non-dominant hand would be mimicking the movements of the dominant hand. Additionally, we anticipate that the non-dominant hand will produce similar muscle activity patterns to that of the dominant hand, making it more difficult for the non-dominant hand to produce correctly inhibited selective stops.

Aims and Hypotheses

We will utilise a selective stop signal task and measure EMG to provide behavioural and physiological window into the inhibitory process underpinning selective inhibitory motor control. We aim to fill the gap in the literature and explore the role of handedness, prior cognitive knowledge and cue type on selective inhibitory control. Firstly, we hypothesise that participants dominant hand will display better inhibitory control in the form of shorter stop signal reaction time, compared to their non-dominant hand. Secondly, we will extend the work of Aron and Verbruggen (2008) that suggests that prior cognitive knowledge in the form of a cue will increase SSRT and reduce the reaction time cost associated with selective stopping. Thirdly, we predict that cues presented in symbol form will result in faster stop signal reaction times and reduce SSC, compared to cues presented in word form. Finally, with respect to covert bursts of muscle activity (used to assess the covert inhibitory process) we predict that prior knowledge will decrease the frequency of bursts of muscle activity on successful inhibited stop trials, compared to the trials where no prior knowledge is presented, and that participants' non-dominant hand will show more frequent bursts of muscle activity on successful inhibited stop trials, compared to their dominant hand.

Method

Participants

Thirty-seven young adults aged between 18 and 36 years (*M*=24, *SD*=5.25) were recruited to participate in a single session experiment lasting approximately two hours. One participant's data was excluded from the final analysis as they did not complete the task accurately. Right- and left-handed participants were recruited in order to test theories of hemispheric dominance in regard to inhibitory control. Twenty-two participants were right handed (mean laterality quotient=79.29) and fifteen were left handed (mean laterality quotient=-64.33), as determined by the modified Edinburgh Handedness Inventory (Oldfield, 1971; Appendix A). Participants were recruited via the University of Tasmania's online recruiting system, SONA, social media (Facebook) and through verbal invitation to fellow peers. Eligibility requirements included being aged between 18-40 years, normal or correct-to-normal vision, and no red-green colour blindness. Participants who were students from the University of Tasmania received two hours course credit and remaining participants were reimbursed a $20 Coles/Myer gift card to compensate them for their time.

Participants were screened for colour-blindness (Ishihara, 1972) (Appendix B) before completing the experiment. Before undertaking the experiment, participants were also given an information sheet (Appendix C), briefed and informed consent was obtained (Appendix D). The experiment had received ethical approval from the Tasmanian Human Research Ethics Committee before commencing (Appendix E).

Materials

Stop Signal Task

Visual stimuli were presented on a computer screen using the Python based software, Psychopy (Peirce, 2009). All stimuli were presented on a black screen for ease of viewing, with green 'go' stimuli, red 'stop' stimuli and white text (Figure 1). Two buttons, from a set of four, were used as the response keys for the experiment. These buttons required minimal force to register a response. The default task was a rapid bimanual go response task, requiring simultaneous button presses with the left and right finger in response to the imperative signal (IS). This consisted of or two green arrows with the left arrow corresponding to the left finger and the right arrow corresponding to the right finger. On 33% of trials, the IS was followed by a stop signal (SS), whereby one of the green arrows would turn red; this required the participant to attempt to stop the button press corresponding to the red arrow while continuing to make a button press corresponding to the green arrow.

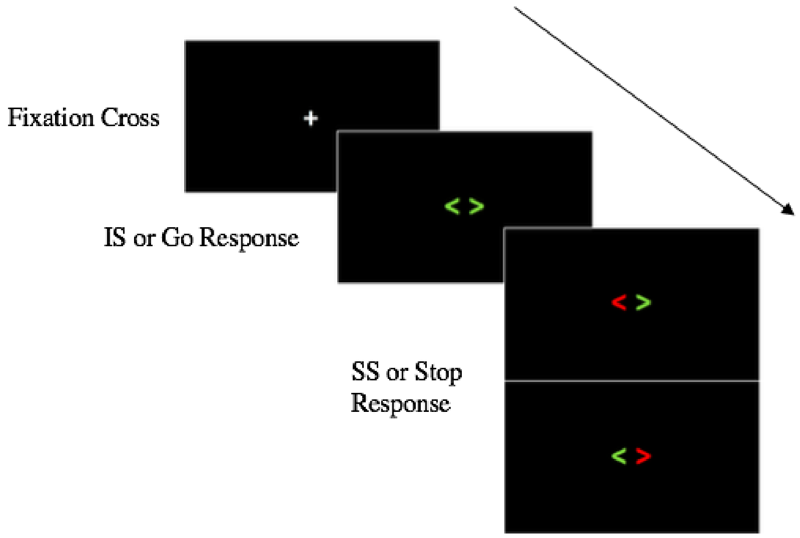

Figure 1. The presentation of the stop signal task stimuli (reactive condition). A fixation cross was presented in the centre of the screen for between 500 to 700ms (this was replaced by a cue in the proactive condition – see figure 2). A blank screen was displayed before the onset of the IS, for 450 - 550ms. The IS was then presented, which on 33% of trials, was then superseded by the SS at stop signal delay (SSD) ms, after the presentation of the IS. The SS consisted of half left stops and half right stops.

In different conditions, the IS was preceded by either a fixation '+' or an informative cue. The reactive condition consisted of a fixation cross being presented in the centre of the screen for 500 - 700ms before the onset of the IS or go signal. We term this condition ‘*reactive*’ as the behavioural response to the selective stop signal could only occur in response to the stop signal itself. In contrast, the proactive condition consisted of a cue being presented, instead of a fixation cross, prior to the onset of the IS for the same time period. The cue informed the participants that if a stop signal was going to occur, which hand would be required to stop. Accordingly, they could *proactively* prepare for which hand they potentially had to stop which would be hypothesised to alter inhibitory control (i.e., *proactive* condition).

Furthermore, the proactive condition consisted of a between-groups manipulation whereby there were two different types of cues, symbol and word (Figure 2). We manipulated the nature of the cue to determine whether this affected its salience, thus, impacted the extent to which it was utilised to facilitate better selective stop performance. There were no other differences in the task between the reactive and proactive conditions.

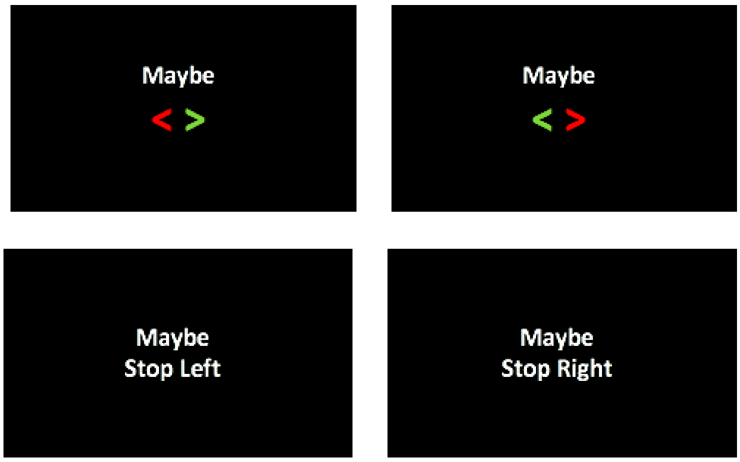

Figure 2. The symbol cue (top panels) and the word cue (bottom panels) in the proactive condition in the current study. The left images cue’s participants that if a stop signal occurs they will stop their left hand, and the right images cue’s participants that if a stop signal occurs they will stop their right hand.

Electromyography

EMG was recorded via three surface adhesive electrodes on each hand, with one electrode being positioned over the belly of the first dorsal interosseous (FDI) muscle of each hand, another electrode being positioned over the distal tendon insertion of the FDI (belly-tendon montage), in addition to a ground electrode positioned on the styloid process (wrist) of the ulna. The FDI was chosen to make a surface recording due to it being activated when the index finger is flexed during the button press response, in addition to it being easily isolated (i.e., little or no muscle cross talk) using surface electrodes. The muscle was located by having the researcher put pressure on the inside of the participant's index finger and having them push back against the researcher's hand, engaging the muscle. The EMG data was fed into a CED amplifier where it was amplified and band-pass filtered prior to being recorded for offline analysis using Signal (CED signal 1401 and 1902 devices). If the participants EMG signal became unexpectedly noisy throughout the experiment, the researcher made a comment to the participant to relax their hands between trials. Relaxation of the FDI muscle enabled the EMG recordings to pick up smaller covert response.

Procedure

Participants were seated at a desk approximately 80cm away from a computer monitor. Their forearms were resting comfortably on the desk in front of them with their index fingers placed on two buttons, which were positioned approximately shoulder width apart. After reading the information sheet (Appendix C) and completing the consent form (Appendix D) participants proceeded with the experiment. Psychopy displayed multiple screens of instructions and information to the participant, as well as the experimenter verbally explaining the task and answering any questions the participant had. A white fixation cross for the reactive condition or a cue for the proactive condition, was presented on the screen for 500 - 700ms to orient the participants attention to where the IS and SS would occur. A blank screen would appear before the IS was displayed, for 450 - 550ms. The varying time of the blank screen is used in order to reduce anticipatory responses for the IS. The IS consisted of the two green arrows, where the right green arrow corresponds to the right hand and indicates a right finger button press is required, and the left green arrow corresponds to the left hand and indicates a left finger button press is required. On the Go trials, consisting of on the IS where no SS was presented. On 33% of trials, a SS was presented. This consisted one of the green arrows turning red (e.g., the right arrow), thus, participants were required to stop the button press corresponding to the red arrow (i.e., the right hand) while continuing to make a button press corresponding to the green arrow (i.e., with the left hand). ‘Left Stop’ and ‘Right Stop’ trials necessitating the left or right response to be inhibited were presented with equal likelihood (16.5% of trials). The SS was presented at SSD ms following the IS, with SSD determined using a staircase algorithm, whereby, the SSD would change such that overall stopping success was 50%. At the start of each condition the SSD would start at 200ms for both left and right hand stop trials, and would change according to the success on each particular stop trial (i.e., independent staircases for left and right stop trials). If the participant made a correct stop on a SS trial the SSD would increase by 50ms, thus, making it harder for them to stop on the following SS trial, or if they failed to stop on an SS trial the SSD would decrease by 50ms, thus, making it easier for them to stop on the next SS trial.

After the response time window (0-1100ms following the IS), feedback would be displayed to participants. When a correct button press was made, the participant’s reaction time would be displayed. If the participant did not make a response for that trial the screen would display ‘missed’. If the participant failed to stop the button press on a SS trial the feedback screen would display ‘failed to stop’. If the participant stopped the incorrect hand on a SS trial the feedback screen would display ‘stopped wrong hand’. If the participant made a bimanual button press but one finger press was more than 50ms delayed from the other finger press, the feedback screen would display ‘please press simultaneously’.

Participants completed the two conditions (reactive and proactive), whereby, each condition had six blocks of 96 trials in each block (576 trials per condition), for a total of 1152 trials across the two conditions. Out of the 576 trials per condition, 192 of those were SS trials, with 96 being right stops and 96 being left stops. Furthermore, nineteen participants completed the *proactive symbol* cue condition, and all remaining participants were allocated to the *proactive word* cue condition. All participants completed the reactive condition. The conditions were counterbalanced, so an equal amount of participants completed the reactive and proactive condition first. Before starting the experiment, a practice block of 30 trials of the IS was completed, to familiarise the participant with the task of responding rapidly and simultaneously with both hands on ‘go’ trials. Additionally, before completing each condition (reactive and proactive) a practice block of 30 trials of that condition was completed, allowing the participant to familiarise themselves with the stopping component (30 trials consisted of go trials, 5 left stop and 5 right stop trials), and of the cue in the proactive condition.

Design and Data Analysis

The practice blocks which consisted of Go trials, and proactive and reactive trials were not analysed.

The independent variables for the behavioural component of the analysis consisted of both within- and between-subject factors. The between-subjects variables were cue type (symbol/word) and handedness (hand dominance) (right/left). The within-subjects variables were condition type (reactive/proactive) and hand used for bimanual go trials and selective stops (left/right). With an additional within-subjects variable, trial type (BiGo/Fail L Stop/Fail R Stop), incorporated once into the analyses as a manipulation check.

Performance on the Go trials was assessed using bimanual go reaction times (BiGo RT). Stopping performance was assessed by calculating the selective stop reaction time (SSRT) for left-stop and right-stop trials. Performance in the ongoing component of the stop-trials were assessed using select stop cost (SSC), calculated by the difference between the RT of the ongoing response (left-hand RT during successful right stop trials: right-hand RT during successful left stop trials) and BiGo RT.

A series of repeated measures four-way and five-way analyses of variance (ANOVA) were conducted. A 2x2x2x2 (condition type: reactive/proactive x hand: left, right x cue type: word/symbol x handedness: left, right) ANOVA was conducted on BiGo RT for both the condition types, to determine whether participants RTs slowed as a result of prior knowledge in the form of a cue. A 2x2x2x2x3 (condition type x hand x cue type x handedness x trial type: BiGo, Fail L Stop, Fail R Stop) was conducted as a manipulation check to determine the RT's of trials where participants were making bimanual button presses and failing to stop. A 2x2x2x2 (condition type x hand: R hand from left stop trial, L hand from right stop trial) x cue type x handedness) ANOVA was conducted on SSC to determine if the provision of a cue resulted in a reduction or abolishment of the expected selective stopping cost. A 2x2x2x2 (condition type x hand: R hand from left stop trial, L hand from right stop trial x cue type x handedness) ANOVA was conducted on SSRT for correct stop on both the left and right selective stop trials to determine if the provision of a cue affected the speed (efficiency) of the inhibitory control process. A 2x2x2x2 (condition type x hand x cue type x handedness) ANOVA was used to analyse participants SSRT for correct stops in the proactive condition only, to determine if the symbol cue was a more salient proactive cue. A 2x2x2x2 (condition type x hand x cue type x handedness) ANOVA was used to analyse SSRT for correct stop on both left stop and right stop trials, to determine if an individual's dominant hand exhibited faster inhibitory control (i.e., shorter SSRT).

A 2x2x2x2 (condition type x hand: R hand from left stop trial, L hand from right stop trial x cue type x handedness) ANOVA was used to analyse EMG for correctly inhibited trials to determine if participants non-dominant hand would produce more frequent partial bursts. Additionally, this ANOVA was used to analyse if trials that presented prior knowledge would reduce the frequency of partial bursts.

The electromyography (EMG) analysis was conducted on a trial-by-trial basis. Fourteen cursors were placed on each data frame, to create thirteen 100ms time windows (see figure 3). One of the windows was set to access EMG prior to the presentation of the IS (background EMG). The other twelve time frames occurred from 0-1100ms post IS. The root mean square (rms) EMG was calculated for each muscle (left and right FDI) in each time window within each data frame, with the baseline (pre-IS) being subtracted from each post-IS rms EMG value. We subsequently determined which time window had the largest rms EMG value, and this would suggest in what time frame the peak of the response occurred. A partial burst was determined to have occurred in correctly inhibited stop trials (left and right stop, analysed separately) if the largest rms value in it on a correctly inhibited trial, exceeded 25% of the maximum rms EMG burst for the corresponding hand averaged across all the BiGo trials. The dependent variable for EMG analysis was then determined as the proportion of correctly inhibited stop trials upon which a partial burst was observed. This was calculated for the stopping hand, in both the left and right selective stop trials.

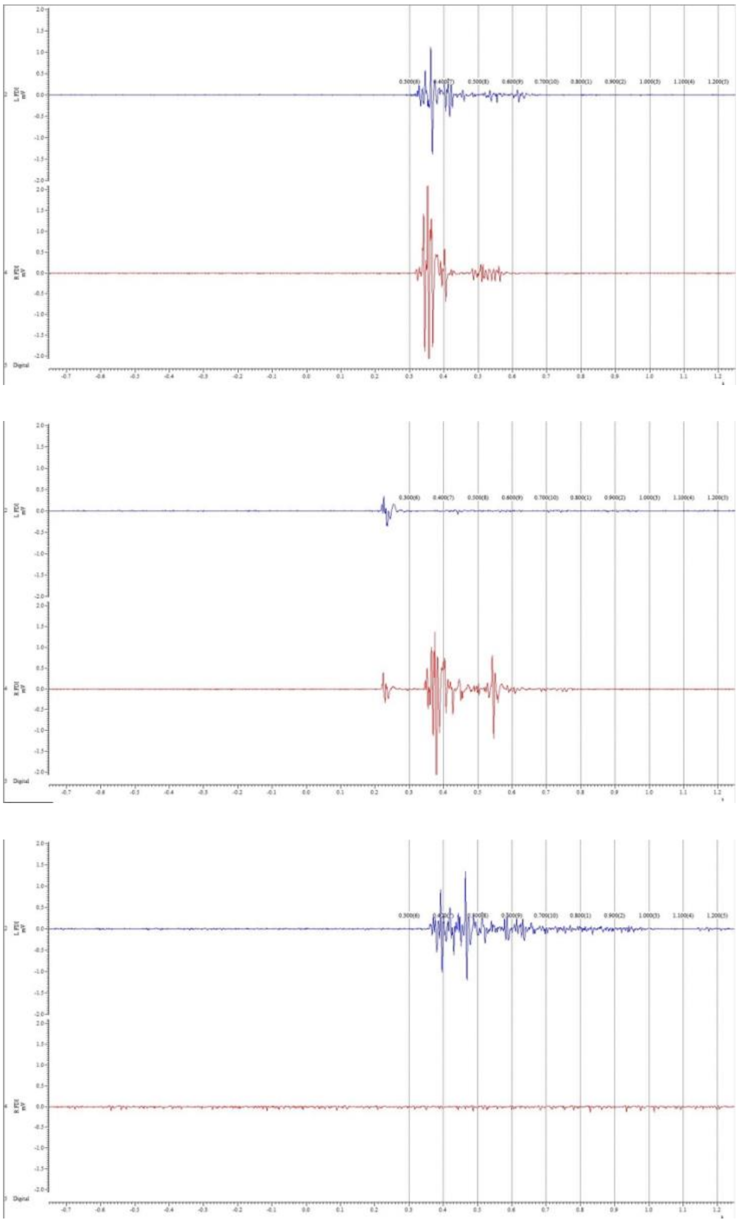

Figure 3. An example of the EMG data (top to bottom): Successful bimanual go trial, successful left-hand stop with evidence of a bimanual partial burst prior to the right hand button press, successful right-hand stop. Blue trace: Left FDI; Red trace: Right FDI.

If the data violated the assumption of sphericity ($\varepsilon < 0.7$), Greenhouse-Geisser epsilon corrections were applied. The level of significance for all analyses was set at p=.05. All main effects that were found were followed up with Bonferroni adjusted post-hoc pairwise comparisons. Effect size values in the form of Cohen's d and partial-eta squared (η_p^2) values were provided. The cut-offs for Cohen's *d* were ≥0.2 = small, ≥0.5 = medium and ≥0.8 = large (Cohen, 1992), and the cut offs for η_p^2 were ≥0.01 = small, ≥0.06 = medium and ≥0.14 = large. Additionally, means (*M*), standard deviations (*SD*)and 95% confidence intervals were presented.

Results

One participant's behavioural data was excluded from the behavioural analyses as their response times were too quick, i.e., they anticipated the IS rather than responding following tis presentation. As such, the staircase algorithm for the SS presentation was unable to function correctly resulting in extremely low stop success rates. The remaining 36 participants completed the task well with no complications.

Behavioural Results:

Stop Success. Participants stopping success averaged at 48% for the reactive condition, and 49% for the proactive condition. Thus, it is evident that the staircase algorithm successfully achieved the expected participant stop success rate of 50% in each condition; as such, differences in performance (i.e., SSRT, SSC) across conditions can be attributed to true behavioural differences.

Bimanual Go Reaction Time. A 2x2x2x2 ANOVA revealed a significant main effect of condition type whereby RTs in the proactive condition (*M*=487ms, SD=138.90, 95% CI [440.09, 534.40]) were significantly longer (~33ms) compared to the reactive condition (*M*=453ms, *SD*=136.56, 95% CI [407.61, 500.34]), $F(1,32)=6.69$, $p=0.014$, $\eta_p^2=.173$. This suggests that the presence of prior cognitive knowledge resulted in a slower reaction time, compared to trials where no cue was presented.

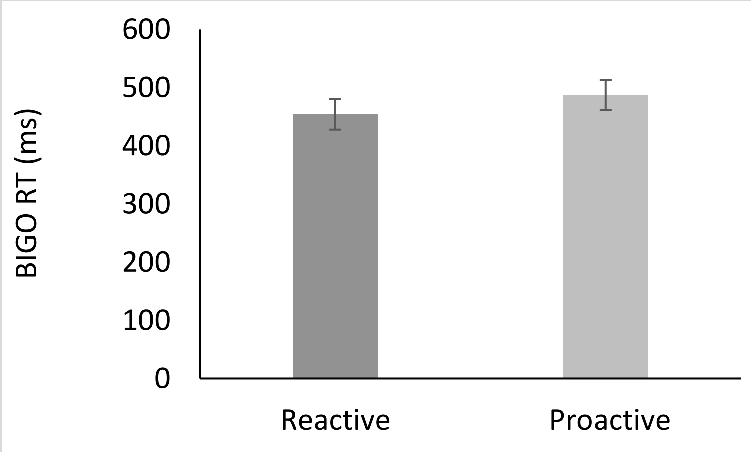

Figure 4. Significant main effect of condition type. Comparison of bimanual go reaction time (ms) between the reactive and proactive conditions. Error bars represent the 95% CIs.

There was also a significant interaction of hand and handedness, *F*(1, 32) = 10.00, *p*=.003, η_p^2=.238. Pairwise comparisons suggest that right-hand dominant participants were faster responding with their right hand (*M*=455ms, *SD*=131.22, 95% CI[396.16, 512.89) compared to their left hand (*M*=458ms, *SD*=129.75, 95% CI[400.76, 515.75). And left hand dominant participants were faster in responding with their left hand (*M*=484ms, *SD*=129.41, 95% CI[409.14, 536.37]) compared to their right hand (*M*=500ms, *SD*=131.35, 95% CI[435.13, 564.53]). All other main effects and interactions were not statistically significant (all *p*>.19, η_p^2<.238).

As a manipulation check, a 2x2x2x2x3 ANOVA was conducted to compare the RT of bimanual go trials (BiGo left, BiGo right) to the RT of failed stop trials (failed stop left for right and left hand stops, failed stop right for right and left hand stops) for both proactive and reactive conditions. The analysis revealed a significant main effect of trial type, *F*(2, 64)=104.027, *p*<0.001, η_p^2= .765, suggesting that BiGo trials had significantly (p<0.001) slower RT's (*M*=470ms, *SD*=132.24, 95% CI[425.72, 515.50] than the left failed stops (*M*=423, *SD*=19.27, 95% CI[383.27, 461.77) by ~48ms and the right failed stops (*M*=425ms, *SD*=117.66 , 95% CI[385.14, 465.04]) by ~46ms. These results are as anticipated, and suggests that when participants RTs were faster than average (BiGos) they were unable to stop, resulting in a failed stop. All other significant and non-significant main effects were not analysed as they were not central to the current research question.

Selective Stop Cost. A 2x2 (condition type x hand) ANOVA was conducted to determine if the provision of a cue reduced selective stop cost (SSC), compared to no cue being presented. The analysis revealed a significant main effect of condition type, $F(1, 32)=44.62$, $p<0.001$, $\eta_p^2= .582$, suggesting that the proactive condition, and therefore prior knowledge, greatly reduced SSC (*M*=61ms, *SD*=32.34, 95% CI[50.57, 72.53]) compared to the reactive condition (*M*=90ms, *SD*=23.10, 95% CI[82.88, 98.58]) by ~ 29ms. All other main effects and interactions were not statistically significant (all $p>.13$, $\eta_p^2<.072$).

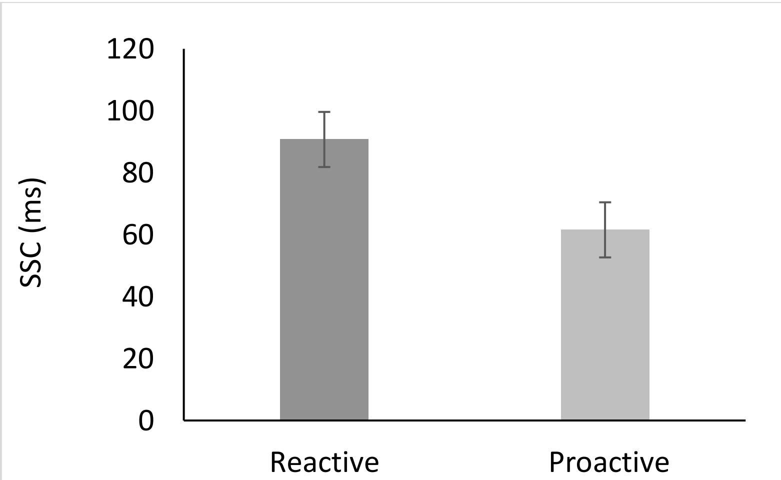

Figure 5. Significant main effect of condition on selective stop cost (ms) between the reactive and proactive conditions. Error bars represent the 95% CIs.

Stop Signal Reaction Time. A 2x2 (condition type x hand) ANOVA was conducted to determine if the reactive condition would result in faster SSRT compared to the proactive condition and, furthermore, if an individual's dominant hand exhibited faster SSRT compared to their non-dominant hand. The analysis revealed that SSRT in the reactive (*M*=198ms, *SD*=27.72 , 95% CI[188.83, 207.63]) and the proactive (*M*=198ms, *SD*=28.68, 95% CI[188.45,207.91]) condition did not significantly differ, $F(1, 32)=<0.001$, $p=.99$,

$\eta_p{}^2$=<0.001. While a statistically significant interaction between condition type and hand, $F(1, 32)=8.30$, $p=0.007$, $\eta_p{}^2= .206$ was observed, pairwise comparisons were not conducted as it was not a central analysis for the current research questions.

Additionally, the analysis revealed that hand dominance did not significantly affect SSRT, $F(1, 32)=1.27$, $p=0.27$, $\eta_p{}^2= .038$. Likewise, there was no statistically significant main effect of cue type (word vs symbol cue) in the proactive condition, $F(1, 32)=.98$, $p=.33$, $\eta_p{}^2=.03$. All other main effects and interactions were not statistically significant (all $p>.17$, $\eta_p{}^2<.057$).

Physiological Results:

A 2x2x2x2 ANOVA was conducted to determine whether the provision of a cue reduced the frequency of the occurrence of partial responses and if an individual's non-dominant hand would produce more frequent partial bursts, compared to their dominant hand. The analysis revealed that there was no significant difference in partial bursts between the reactive (*M*=23%, *SD*=16.05, 95% CI[17.79, 28.52]) and the proactive condition (*M*=20%, *SD*=12.46, 95% CI[16.02, 24.35]), $F(1, 33)=1.81$, $p=.19$, $\eta_p{}^2=.052$. There was a main effect of hand suggesting that overall participants right hand displayed significantly more frequent partial bursts (*M*=26%, *SD*=18.30, 95% CI[19.85, 32.28]) compared to their left hand (*M*=17%, *SD*=11.82, 95% CI[13.26, 21.28]). Additionally, there was no significant interaction of hand and handedness, therefore, participants non-dominant hand did not display significantly more frequent covert bursts compared to their dominant hand, $F(1, 33)=.35$, $p=56$, $\eta_p{}^2=.011$.

In addition, there was a significantly large interaction of cue type (symbol, word), handedness and condition type (reactive, proactive), $F(1, 33)=4.64$, $p=.039$, $\eta_p{}^2 = .123$. Importantly, the pairwise comparisons suggest that left-hand dominant participants who undertook the symbol cue type within the proactive condition, displayed a significantly larger amount of frequent partial bursts in the reactive condition (*M*=29%, *SD*=14.73 95% CI [18.63, 41.27]) compared to the proactive condition (M=19%, *SD*=11.45, 95% CI [10.65, 28.22], *p*=.031, 95% CI [1.05, 19.99], *d*=.76 (figure 6). This effect was not significant for left-hand dominant participants in the word condition, *p*=.62, 95% CI [-12.64, 7.61]. Although, not significant, the pairwise comparison display that right-hand dominant participants had the opposite effect to the left-hand dominant participants. Right-hand dominant participants who completed the word cue type within the proactive condition, displayed more frequent partial bursts when comparing the reactive condition (*M*=22%, *SD*=5.01, 95% CI [12.11, 31.42]) to the proactive condition (*M*=17%, *SE*=11.63, 95% CI [9.33, 24.32]), *p*=.22, 95% CI [-3.14, 13.02], *d*=.56 (figure 7). This effect was similarly not significant for right-hand dominant participants in the symbol condition, *p*=.79, 95% CI [-9.13, 7.03].

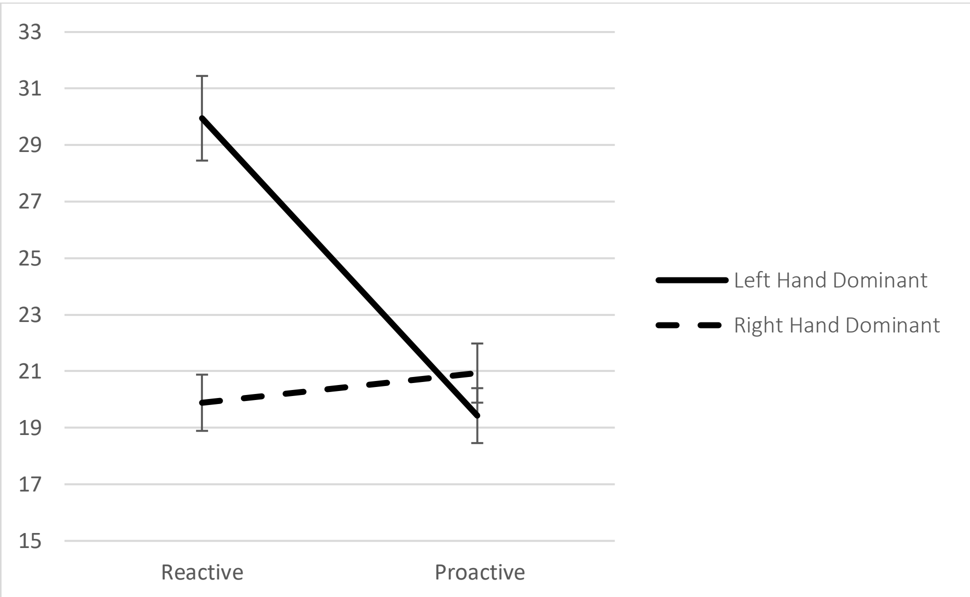

Figure 6. Rate of partial bursts in the symbol cue type condition within the proactive condition comparing between right- and left-hand dominant participants: Interaction between cue type, handedness and cue type. Error bars represent 95% confidence intervals.

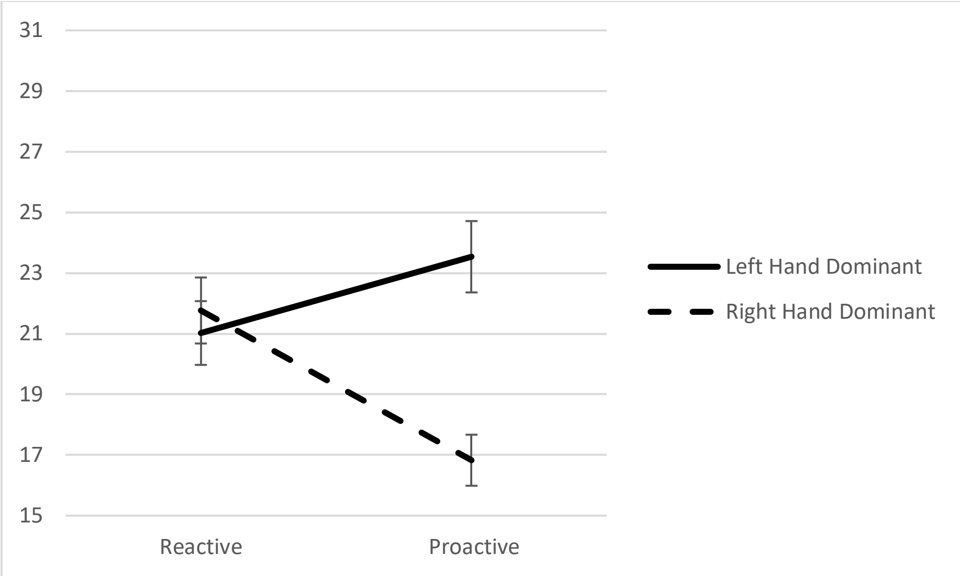

Figure 7. Rate of partial bursts in the word cue type condition within the proactive condition comparing between right- and left-hand dominant participants: Interaction between cue type, handedness and cue type. Error bars represent 95% confidence intervals.

Furthermore, the analysis revealed a significant interaction of condition type (reactive, proactive), hand (left, right) and cue type (symbol, word), $F(1, 33)=6.06$, $p=0.019$, $\eta_p^2= .155$. However, this interaction was not further analysed as it was not central to the current research question. All additional main effects and interactions were not statistically significant (all $p>.19$, $\eta_p^2<.052$).

Discussion

The current study used behavioural measures that assessed performance in a selective stopping task in combination with a measurement of muscle activity patterns (i.e., physiological data). This permits us an understanding of the underlying inhibitory processes that may not be overtly expressed by considering behaviours alone. Specifically, we aimed to explore selective inhibitory control, investigating how prior cognitive knowledge, the type of knowledge presented, and hand dominance can impact upon the efficacy of inhibitory control.

The effect of prior cognitive knowledge and cue type on behavioural measures of selective stopping

The current research provided results that are consistent with previous research suggesting that the provision of prior knowledge can reduce the reaction time delay associated with selective stopping (Cai et al., 2001; Claffey et al., 2010). Specifically, we found that the reaction time delay when participants were presented prior knowledge before the onset of the IS, compared to when they were not presented with prior knowledge was a difference of 29ms. These findings are similar to those found by Claffey and collegeues (2010) whose research suggested that the difference in the delay between a foreknowledge and no foreknowledge condition was 28ms, and Aron and Verbruggen (2008) who found a difference of 19ms. Our findings are consistent with the view that prior knowledge allows creation of a rule regarding the possible stopping behavior that may need to be implemented (Aron & Verbruggen, 2008). And it is this rule that is suspected to have reduced the SSC, as participants no longer had to globally stop all behaviours and process what behavior they had to overtly behave next, rather they only had to stop and overtly behave the rule that they had planned prior to the onset of the IS. However, the provision of a cue did not entirely eliminate the delay associated with selective stopping, therefore, there is still a cost associated with selective stopping.

Our results are inconsistent with previous research that suggests that prior knowledge in selective stopping tasks will increase SSRT as it will evoke the indirect stopping pathway, thereby causing a less efficient stopping process (Aron & Verbruggen, 2008; Coxen et al., 2007). Along with having multiple components to execute with a selective stop (stopping all prepared actions and re-initiating the appropriate (new) response), compared to a global stop, the indirect pathway additionally has more synapses, thus, the reaction time of selective stopping is slower (Xu, Westrick & Ivry, 2014). The current research suggests that a proactive cue, while improving the efficacy of the ongoing task, does not necessarily come with the costs of slowing SSRT. Our results indicate that the SSRT of the trials where prior knowledge was presented were not different to trials that did not present prior knowledge. To clarify, trials that are presented without a cue are more likely to utilise the hyperdirect pathway, faster pathway, whereas it is proposed that presenting a cue will encourage participants to use the indirect, slower, more specific pathway. We suspect that the use of prior knowledge was not invoking an indirect (selective) stopping pathway majority of the time. Similar to the acknowledgment made by Aron and Verbruggen (2008), we suggest that our participants were using a combination of global and selective stop mechanisms, as SSRT was in the proactive condition was not slower as anticipated. Thus, the use of a global stop mechanism on majority of trials would explain the faster stop signal reaction time in the proactive condition. We question whether our participants were prioritizing the *speed* of the stopping rather than over *precision* (or selectivity) of the stopping, and therefore, they were tending to use the faster, hyperdirect pathway, over the slower indirect pathway.

Xu, Westrick and Ivry (2015) suggest that with a combination of prior knowledge, training and incentives, participants can enhance their selective stopping behaviours in the form of reduced SSC, while exhibiting SSRT's that were not significantly different in the proactive and reactive trials. As the current research consisted of 576 trials with prior knowledge, compared to previous research which consists of approximately 200 trials (Aron & Verbruggen, 2008) to 360 trials (Coxon et al., 2007), it might be assumed that participants in the current study had longer to practice and acquaint themselves to fully utilize the cues. Therefore, it is plausible that a training or practice effect occurred, resulting in similar SSRT for trials with prior knowledge and no prior knowledge. Such training, however, did not, eliminate the selective stop cost, as the reaction time delays in the proactive condition were still considerable.

The current paradigm extended previous work by including a manipulation of the manner in which the proactive cue was presented. Specifically, prior knowledge was presented to participants in either a word or symbol form. Previous research has primarily utilised word-based cues; however, we propose that presenting the cuing information in a similar form to the presentation of the imperative and stop symbols (i.e., symbol-based), may enhance its salience, and thus, result in a more efficient use of the cue. However, the results suggest that the manner in which the prior knowledge was presented does not significantly impact the interpretation of the cue or the effectiveness of the cue rate facilitating fast and selective stopping. Therefore, it can be proposed that future research can use either word or symbol-based cues as they do not significantly differ in the effectiveness. Additionally, research in the field using either one of the cue types can be generalized to both symbol and word-based cues.

The effect of hand dominance on behavioural measures of selective stopping

The current research results suggest that on bimanual go trials, participants dominant hand was significantly faster than their non-dominant hand, thus, confirming the results of Shen and Franz (2005). Therefore, we suggest that on BiGo trials, the dominant hand is leading the movement and the non-dominant hand is locked to or following the movement of the dominant hand. However, inconsistent with Shen and Franz (2005) previous research, this effect was not found in selective stop trials, with our results suggesting that there is no significant difference in reaction time of the ongoing hand making the button press, between the dominant and non-dominant hand.

Physiological Measures

The current research used trial by trial analysis of muscle activation as a means to detect covert responses; specifically, on correctly inhibited selective stop trials, a burst of muscle activity in the successfully inhibited hand is referred to as a partial covert response. Such partial responses can be viewed as evidence that descending neural signals (in response to an imperative go signal) that result in activation of the responding muscle can be cancelled, or shut off, following the presentation of a subsequent stop signal, prior to enough force be generated for an overt response to be registered. In the current study, we found that on 22% of successful stop trials partial responses were observed in the inhibited hand. This is evidence to suggest that a prepared movement can be inhibited, despite the movement already being initiated from M1, contrary to the De Jong et al., (1990) point of no return hypothesis. Their hypothesis suggests that if M1 had prepared a movement, then no partial response would be evident, as an overt behavior would have occurred and the SS would not have been correctly inhibited. The results displayed in the current study are consistent with previous research (Read, 2017), that also disconfirms De Jong et al., (1990) point of no return hypothesis, thus, we propose that muscle activation can be inhibited or changed after the movement has been prepared by M1, similar to that suggested by McGarry and Franks (1997).

We hypothesised that on correctly inhibited trials the non-dominant hand would produce more frequent covert bursts, as research suggests that the non-dominant hand is more closely coupled to the dominant therefore, it is more likely to show behaviours mimicking the dominant hand (which would be making a button press) (MacDonald et al., 2012). Our results however did not confirm this hypothesis. However, our research revealed that overall participant's right hand displayed more frequent covert bursts than their left hand, irrespective of handedness. Shen and Franz (2005) propose that right-hand dominant individuals have a stronger hemisphere dominance, thus, they have a stronger bias to their left (dominant) hemisphere. In contrast, left-hand dominant individuals do not have an as strong bias towards a dominant hemisphere and therefore, they do not have a strong bias towards either hemisphere. In combination with the current studies findings and those of Shen and Franz (2005), it is suggested that for left-hand dominant individuals, the non-dominant hand may not be as tightly coupled to the dominant hand and produce more frequent partial bursts. Rather, we suggest that partial bursts occur as a result of the dominant, most used hand unconsciously initiating a behavior in response to stimuli as it would usually do. Thus, the right hand displayed more frequent covert bursts as in right hand dominant individuals it is most often used, and in left hand dominant individuals behavior is not as strongly predisposed to that hand. The environmental set up for right-hand dominant individuals could support why left-hand dominant individuals had more frequent partial bursts in their right hand. The environment is created for right hand dominant individuals, and left hand dominant individuals often have to adapt to living a lifestyle where they can function using their non-dominant hand, thus, they are more frequently using their non-dominant hand compared to right hand dominant individuals.

An unexpected finding was that there was an interaction between condition type (reactive, proactive), cue type (word, symbol) and handedness on the frequency of covert muscle bursts in correctly inhibited trials. Left-hand dominant individuals who were presented with prior knowledge in the form of a symbol cue in the proactive condition displayed significantly less frequent partial bursts, with a very large effect size, compared to when they did not have the use of a cue in the reactive condition. In contrast, the data for the right-hand dominant individuals who were presented with prior knowledge in the form of a word cue during the proactive condition tended to exhibit less frequent partial bursts compared to when they performed in the reactive condition. Although not significant, the effect between the conditions was still relatively large. These results may be indicative of an interference effect when the hemisphere that is controlling the execution of the button press (and inhibition thereof) is also required to process the type of cue. For example, the left hemisphere specialises in language comprehension and production, but it is also the hemisphere that the initiation of right hand movement occurs, due to the crossed motor system (Knecht, 2000). Thus, when right-hand dominant individuals M1 (in their left hemisphere) prepares for and initiates a button press with their right hand, that hemisphere is also being used to comprehend the word cue, which hypothetically could lead to interference effects as an overload of information is occurring in that one hemisphere. Similarly, the right hemisphere specialises in the perception of non-verbal information, therefore, when left-hand dominant individuals are preparing for a movement using their dominant (left hand) the right-hemispheres M1 is preparing a left-hand movement, and the right hemisphere is also being used to process the symbol cue. Therefore, we suggest that future research analyse this finding using functional imagining techniques to see if there is an interference effect occurring when the hemisphere that specialises in the processing of the specific cue is also the dominant hemisphere for the behavioural response.

Limitations and Future Research

Independently, the two techniques used in the current research to analyse inhibitory control, the stop signal task and EMG, have a large number of empirical studies suggesting that they are accurate and reliable measures of inhibitory control. Although, few studies have combined the two techniques in this manner to provide a behavioral and physiological viewpoint on the same inhibitory task. However, once a greater body of evidence is developed to provide basis for the interpretation of covert inhibitory control response, it is believed that the combination of these techniques will be widely accepted as strong evidence for measuring inhibitory motor control. The use of the EMG exhibits great potential for future research wanting to analyse the underlying covert behaviours associated with movement, in both health, aging and diseased individuals.

Although EMG analysis of covert muscle activity is in its early stages of inhibitory control and shows good potential, there is no standard rule when analyzing and interpreting the data. Therefore, the analysis of EMG data on inhibitory control needs to be fine-tuned and a standard way of analyzing the data should be developed allowing for accurate repetition and reliability for future research.

In the current research, eight participants displayed a substantial slowing effect in the proactive condition overall; that is, on bimanual go trials, these participants exhibited reaction times that were substantially slower than their comparable bimanual go response in the reactive condition. We were concerned as to whether these participants could drive a slowing effect, whereby the SSRT for the proactive condition may be driven by the slowing of the go response in those participants. Due to these considerations, we ran the analysis with and without these participants, but we found no significant differences occurred in the interpretation of the results, specifically in SSRT and SSC between the reactive and the proactive condition. This is a limitation of the stop signal task used in the current research, as participants can slow their reactions time in anticipation of the SS (stop signal). In doing this, the staircase algorithm is no longer effective as participants correctly stop on majority of the SS trials rather than on the desired 50% of trials. Additionally, in waiting to respond the SS can have a ceiling effect, whereby because the participant is correctly stopping on majority of SS trials, the SSD gets longer, thus, the SS is presented after a longer time frame and at some point it will no longer be displayed on the screen as the SSD will be longer than the time that the screen time is active for. Although this extreme example did not occur in the current research, and our stop success % displays that participants were stopping correctly on approximately 48-49% of trials, it is a limitation of the task and should be taken into consideration when opting to use the stop signal task in the future. One possible solution to circumvent such slowing is to implement anticipated response tasks (Coxen et al., 2006, 2007) where the 'go' response is time-locked to a reliable stimulus (e.g. a bar slowing rising up the screen which is stopped at a target by the participant pressing/lifting a button); stopping trials are implemented by stopping the bar artificially prior to it reaching the target, in which the participant is required to counterman their own response.

We propose that future research use functional imaging techniques to look into two aspects that the current research has identified. Firstly, we suggest that these imaging techniques confirm the theories that suggest that global and selective stopping are derived from two separate neural pathways; the hyperdirect pathway active in global stopping (faster stopping) and the indirect pathway active during selective stopping (slower stopping). Specifically, as our research and additional research does not support this hypothesis that the indirect pathway is always utilised during selective stop trials. Secondly, we suggest that future research use these techniques to see if there is an interference effect occurring when the hemisphere that specialises in the processing of the specific cue (either word cue processed by the left hemisphere or symbol cue processed by the right hemisphere) is also the dominant hemisphere for the behavioural response.

Further analysis using computational modeling is suggested for future research, as it will allow us to understand the neural and physiological processes that underlie observable human behavior which standard analyses using central tendendies (e.g. mean RT, mean SSC, mean SSRT) may not detect (Forstmann & Wagenmakers, 2015). It is believed that such modelling might reveal subtle handedness differences and differences between the reactive and proactive conditions that were not revealed using the current (traditional) statistical technqiues. The current study's EMG data will also be helpful in informing the computational modeling, as it can assist in setting parameters within the model that is based on true neuroscience data. However, it is acknowledged that such modelling/analysis was beyond the scope of the current honours project, and it is therefore suggested that further research use this technique to build on the current findings of handedness, prior knowledge and cue type.

Additionally, we suggest that an analysis of older cohorts using the same task as the current research will provide insight into healthy aging and assist with understanding how inhibitory control changes across the lifespan. Additional research into this area will provide insight into how and why the inhibitory mechanisms in populations such as Tourette's, ADHD and healthy aging may fail. More specifically, the current research can build on previous research to help inform us on hand and hemisphere dominant effects, as well as how prior cognitive knowledge can be used to assist these populations in inhibitory motor control.

Conclusion

The current study investigated performance of, and the mechanisms associated with inhibitory motor control, specifically using prior cognitive knowledge to enhance stopping performance on a selective stop signal task. Additionally, EMG was used to assess the frequency of covert muscle activity on correctly inhibited trials. Participants hand dominance was recorded as it was hypothesised that the non-dominant hand would produce slower SSRT, and more frequent covert bursts. Consistent with the literature, the reaction time cost associated with selective stopping was reduced as a result of presenting a cue before the onset of the IS (Cai et al., 2001, Claffey et al., 2010). However, contrary to the existing literature, the current study's findings did not suggest that the SSRT increased as a result of prior knowledge. We propose that this may have occurred as participants were not always using the selective, indirect pathway which is suggested to elicit a slower response. Rather, we suggest that participants were more frequently using the hyperdirect, fast pathway to initiate a quick response, which would result in a faster SSRT, similar to that of the response made in non-cued trials.

Additionally, prior knowledge was presented in two different forms, word and symbol, to assess if the presentation of the cue altered stopping performance. The results of the current study display that the type of cue presented does not alter the effectiveness of the cue on stopping performance, rather, the results do suggest that the type of cue may have an interference effect with participants hand dominance, and impact the frequency of partial bursts seen in inhibiting hand.

Research on inhibitory control is important in understanding how and why these mechanisms may fail in populations where inhibitory motor control is impaired, such as Tourette's, ADHD and healthy aging individuals. The findings from the current study contribute to this body of literature that aims to assist these individuals in adapting to changes in the environment.

References

Aron, A. R. (2011). From reactive to proactive and selective control: developing a richer model for stopping inappropriate responses. *Biological Psychiatry*, *69*(12), e55–e68. http://doi.org/10.1016/j.biopsych.2010.07.024

Aron, A. R., & Verbruggen, F. (2008). Stop the presses: dissociating a selective from a global mechanism for stopping. *Psychological science*, *19*(11), 1146-1153. doi: 10.1111/j.1467-9280.2008.02216.x.

Band, G. P., Van Der Molen, M. W., & Logan, G. D. (2003). Horse-race model simulations of the stop-signal procedure. *Acta psychologica*, *112*(2), 105-142. doi: 10.1016/S0001-6918(02)00079-3.

Bäumer, T., Dammann, E., Bock, F., Klöppel, S., Siebner, H. R., & Münchau, A. (2007). Laterality of interhemispheric inhibition depends on handedness. *Experimental Brain Research*, *180*(2), 195-203. doi: 10.1007/s00221-007-0866-7.

Byblow, W. D., Lewis, G. N., Stinear, J. W., Austin, N. J., & Lynch, M. (2000). The subdominant hand increases the efficacy of voluntary alterations in bimanual coordination. *Experimental Brain Research*, *131*(3), 366-374. doi: 10.1007/s00221990027.

Cai, W., Oldenkamp, C. L., & Aron, A. R. (2011). A proactive mechanism for s elective suppression of response tendencies. *Journal of Neuroscience*, *31*(16), 5965–5969. doi: 10.1523/JNEUROSCI.6292-10.2011.

Carson, R. G., Thomas, J., Summers, J. J., Walters, M. R., & Semjen, A. (1997). The dynamics of bimanual circle drawing. *The Quarterly Journal of Experimental* Psychology Section A, 50(3), 664-683. https://doi.org/10.1080%2F713755721

Claffey, M. P., Sheldon, S., Stinear, C. M., Verbruggen, F., & Aron, A. R. (2010).

Having a goal to stop action is associated with advance control of specific motor representations. *Neuropsychologia*, *48*(2), 541-548. doi:10.1016/j.neuropsychologia.2009.10.015.

Coxon, J. P., Stinear, C. M., & Byblow, W. D. (2006). Intracortical inhibition during volitional inhibition of prepared action. *Journal of neurophysiology*, *95*(6), 3371-3383. doi: 10.1152/jn.01334.2005.

Coxon, J. P., Stinear, C. M., & Byblow, W. D. (2007). Selective inhibition of movement. Journal of neurophysiology, 97(3), 2480-2489. doi: 10.1152/jn.01284.2006.

De Jong, R., Coles, M. G., Logan, G. D., & Gratton, G. (1990). In search of the point of no return: the control of response processes. *Journal of Experimental Psychology: Human Perception and Performance*, *16*(1), 164. doi: 10.1037/0096-1523.16.1.164.

De Jong, R., Coles, M. G., & Logan, G. D. (1995). Strategies and mechanisms in nonselective and selective inhibitory motor control. *Journal of experimental psychology: Human perception and performance*, *21*(3), 498. doi: 10.1037/0096-1523.21.3.498.

Duque, J., Greenhouse, I., Labruna, L., & Ivry, R. B. (2017). Physiological markers of motor inhibition during human behavior. *Trends in neurosciences*, *40*(4), 219-236. doi: 10.1016/j.tins.2017.02.006.

Fay, N., Lister, C. J., Ellison, T. M., & Goldin-Meadow, S. (2014). Creating a communication system from scratch: gesture beats vocalization hands down. *Frontiers in Psychology*, *5*, 354. doi: 10.1075/pc.22.2.05fay.

Forstmann, B. U., & Wagenmakers, E. J. (2015). Model-based cognitive neuroscience: A conceptual introduction. In *An introduction to model-based cognitive neuroscience* (pp. 139-156). Springer, New York, NY. doi: 10.1007/978-1-4939-2236-9_7.

Fujiyama, H., Hinder, M. R., Schmidt, M. W., Garry, M. I., & Summers, J. J. (2012). Age-related differences in corticospinal excitability and inhibition during coordination of upper and lower limbs. *Neurobiology of aging*, *33*(7), 1484-e1. doi: 10.1016/j.neurobiolaging.2011.12.019.

Garry, M. I., & Franks, I. M. (2000). Reaction time differences in spatially constrained bilateral and unilateral movements. *Experimental brain research*, *131*(2), 236-243. doi: 10.1007/s002219900299.

Gillies, A. J., & Willshaw, D. J. (1998). A massively connected subthalamic nucleus leads to the generation of widespread pulses. *Proceedings of the Royal Society of London B: Biological Sciences*, *265*(1410), 2101-2109.

Ishihara, S. (1972). The series of plates designed as a test for colour deficiency. 38 plates edition. Kanehara Trading Inc. Tokyo: Shuppan.

Knecht, S., Dräger, B., Deppe, M., Bobe, L., Lohmann, H., Flöel, A., & Henningsen, H. (2000). Handedness and hemispheric language dominance in healthy humans. *Brain*, *123*(12), 2512-2518. doi: 10.1093/brain/123.12.2512.

Ko, Y. T., & Miller, J. (2011). Nonselective motor-level changes associated with selective response inhibition: evidence from response force measurements. *Psychonomic bulletin & review*, *18*(4), 813-819. doi: 10.3758/s13423-011-0090-0.

Lappin, J. S., & Eriksen, C. W. (1966). Use of a delayed signal to stop a visual reaction-time response. *Journal of Experimental Psychology*, *72*(6), 805. doi: 10.1037/h0021266.

Logan, G. D., & Cowan, W. B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological review*, *91*(3), 295. doi: 10.1037/0033-295X.91.3.295.

MacDonald, H. J., McMorland, A. J., Stinear, C. M., Coxon, J. P., & Byblow, W. D. (2017). An activation threshold model for response inhibition. *PloS one*, *12*(1), e0169320. doi: 10.1371/journal.pone.0169320.

MacDonald, H. J., Stinear, C. M., & Byblow, W. D. (2012). Uncoupling response inhibition. *Journal of neurophysiology*, *108*(5), 1492-1500. doi: 10.1152/jn.01184.2011.

McGarry, T., & Franks, I. M. (1997). A horse race between independent processes: Evidence for a phantom point of no return in the preparation of a speeded motor response. *Journal of Experimental Psychology: Human Perception and Performance*, *23*(5), 1533. doi: 10.1037/0096-1523.23.5.1533.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologica*, *9*(1), 97–113. doi:10.1016/0028-3932(71)90067-4.

Peirce, J. W. (2009). Generating stimuli for neuroscience using PsychoPy. *Frontiers in Neuroinformatics*, 2(10), 1–8. doi:10.3389/neuro.11.010.2008.

Read, A. (2017). Electromyographic analysis of covert responses during global and selective stop-signal tasks: implications for theoretical models of stopping behaviour (Unpublised honour's thesis). University of Tasmania, Australia.

Schachar, R., Mota, V. L., Logan, G. D., Tannock, R., & Klim, P. (2000). Confirmation of an inhibitory control deficit in attention-deficit/hyperactivity disorder. *Journal of abnormal child psychology*, *28*(3), 227-235. doi: 10.1023/A:1005140103162.

Servant, M., White, C., Montagnini, A., & Burle, B. (2015). Using covert response activation to test latent assumptions of formal decision-making models in humans. *Journal of Neuroscience*, *35*(28), 10371-10385. doi: 10.1523/JNEUROSCI.0078-15.2015.

Shen, Y. C., & Franz, E. A. (2005). Hemispheric competition in left-handers on bimanual reaction time tasks. *Journal of Motor Behavior*, *37*(1), 3-9. doi: 10.3200/ JMBR.37.1.3-9.

Summers, J. J., Davis, A. S., & Byblow, W. D. (2002). The acquisition of bimanual coordination is mediated by anisotropic coupling between the hands. *Human movement science*, *21*(5-6), 699-721. doi: 10.1016/S0167-9457(02)00151-3.

Summers, J., Krampe, R, T., Engbert, R., & Kliegl, R. (2002). Practice and training in bimanual coordination tasks: Strategies and constraints. *Human Movement Timing And Coordination*, (1), 166. https://doi.org/10.1006/brcg.2001.1311.

Verbruggen, F., & Logan, G. D. (2008). Response inhibition in the stop-signal paradigm. *Trends in cognitive sciences*, *12*(11), 418-424. doi: 10.1016/j.tics.2008.07.005.

Verbruggen, F., & Logan, G. D. (2009). Models of response inhibition in the stop-signal and stop-change paradigms. *Neuroscience & Biobehavioral Reviews*, *33*(5), 647-661. doi: 10.1016/j.neubiorev.2008.08.014.

Appendix A: Handedness Inventory

Handedness Inventory

For each of the activities below, please tell us:

1. Which hand do you prefer for that activity?
2. Do you *ever* use the other hand for the activity?

	Preferred hand?		Ever use other hand?	
Writing	L	R	Y	N
Drawing	L	R	Y	N
Throwing	L	R	Y	N
Using scissors	L	R	Y	N
Using a toothbrush	L.	R	Y	N
Using a knife (without fork)	L	R	Y	N
Using a spoon	L	R	Y	N
Using a broom (upper hand)	L	R	Y	N
Striking a match	L	R	Y	N
Opening a box (lid)	L	R	Y	

Do you ever confuse left and right? ....

How many people in your immediate family are left handed? ....

Appendix B: Colour Blind Test Plates (Ishihara, 1972)

Plate 1: Demonstration plate. Correct answer is 12. People with red/green colour blindness should also see the number 12

Plate 2: Correct answer is 8

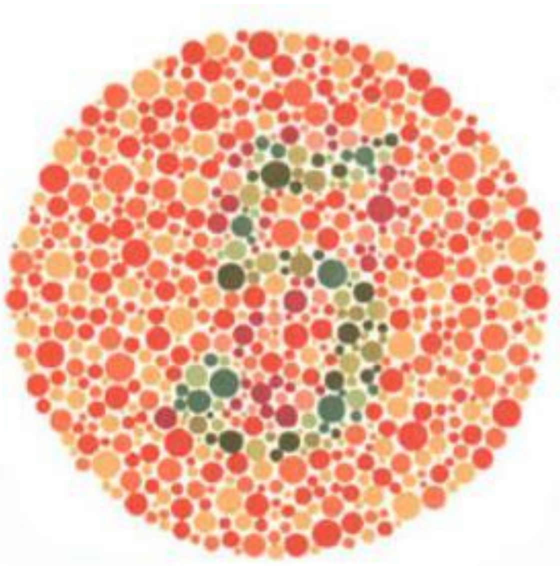

Plate 6: Correct answer is 5

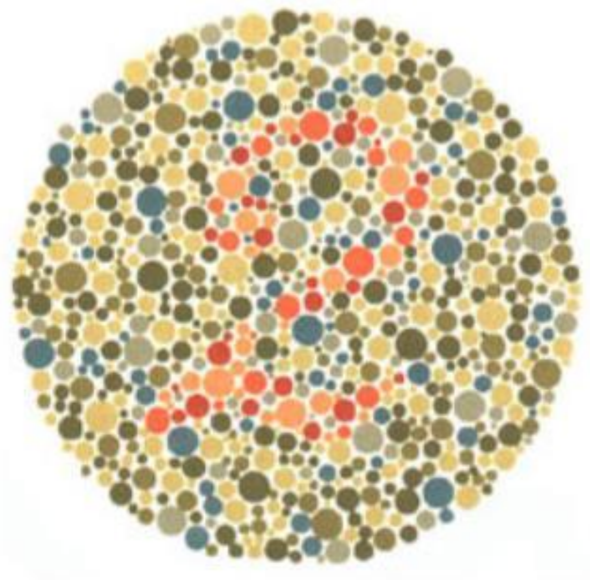

Plate 10: Correct answer is 2

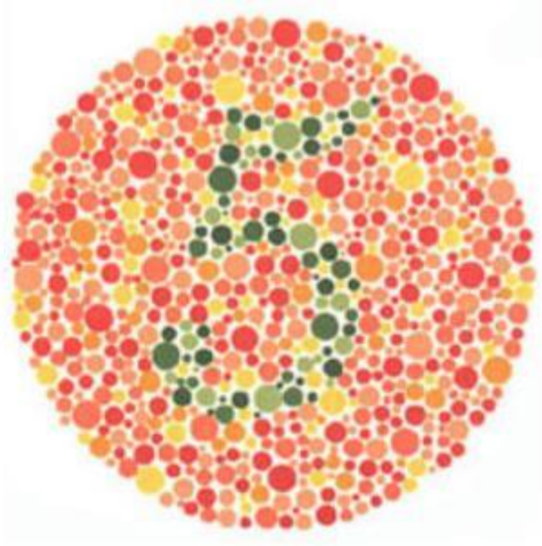

Plate: 14: Correct answer is 5

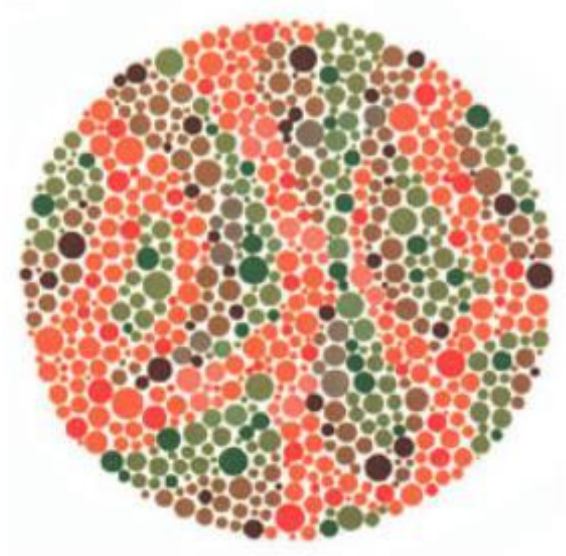

Plate 18: Participants with intact red/green colour vision should see no number.

Appendix C: Information Sheet

PARTICIPANT INFORMATION SHEET

Understanding the influence of cognitive processing and brain connectivity on rapid motor responses across the lifespan: A model-based neuroscience approach

Invitation

You are being invited to take part in a research study funded by the Australian Research Council (FT150100406). The research team are:

Lead Investigator: Dr Mark Hinder

Co-Investigators: Prof Andrew Heathcote, Ms Tess Nikitenko

Student investigators: Mr Rohan Puri, Mr Angus Reynolds, Mr Roderick Garton, Ms Elise Yaxley

What is the purpose of this study?

The study will further our understanding of rapid decision-making processes, and inhibitory control in healthy young and older participants.

Why have I been invited to participate?

You have been asked to participate as you fulfil the age requirements of our intended cohorts, and have expressed an interest in participating (either via SONA or via other advertisement/email response)

What will I be asked to do?

After reading this information sheet you will be asked to provide your (written) consent to participate in the study.

You will then be asked to respond to visual (presented on a black box or computer screen) or auditory stimuli with rapid finger movements or pushing buttons with one or both index fingers. Often, a choice will have to be made as to whether the visual stimulus requires a left or right hand response (decision-making task). This decision may depend on the location or colour of the stimulus, or a perceptual judgement. Occasionally the stimulus may change (e.g., a green go signal turns red, or a red stop signal is superimposed over the perceptual decision task), which will require the participant to cancel the planned response.

In some experiments, EMG will be collected from muscles of your hands and forearms. To ensure the best possible recording, the skin will be prepared by scrubbing it with a mildly abrasive paste and then cleaning it with an alcohol wipe. Self-adhesive recording electrodes will then be placed on the muscle/s of interest and activity recorded to a personal computer for offline analysis.

Sessions may last up to 2.5 hours including all set-up including information and consent, experimentation, breaks and final de-brief. Experiments will be conducted in the Sensorimotor and Ageing Research Laboratories (Psychology Research Centre, Ground Floor) or the TasCL Laboratory (Social Sciences Bldg, Room 228), both located at the Sandy Bay Campus of UTAS, part of School of Medicine, Division of Psychology. If multiple sessions are required, participants will be informed of this prior during the recruitment process; if multiple sessions are required, at least 24-48 hours will be provided between sessions.

The investigator will inform you of exactly what task you will be doing today, how long it will take, whether muscle recordings are required, and whether multiple sessions are required. You will also receive specific instructions on the computer screen while undertaking the task.

Are there any possible benefits from participation in this study?

By participating in the study you are assisting our ongoing research projects which aim to improve the understanding of decision-making and inhibitory control across the lifespan.

You will either receive research credit for participating (via the SONA system – 1 credit per 1 hour completed), $20 Coles-Myer gift card per session, or entered into a draw to win a Coles-Myer gift card ($50/$100/$150, depending on the study size; please ask the investigator if you are unsure which category you fall into).

Are there any possible risks from participation in this study?

While the decision-making tasks are not physically demanding you will be asked to perform multiple blocks of up to ~100 responses (up to ~8 mins per block). To minimise physical and mental fatigue (due to concentrating on the screen, holding hands on buttons), frequent rest periods will be provided throughout the session. We encourage you to stand and stretch, have a drink of water, or have a short walk during these breaks.

While the adhesives used on the electrodes used to record muscle activity are hypoallergenic some participants may feel minor irritation, especially on removal of the electrodes upon completion of the experiment.

What if I change my mind during or after the study?

You are free to withdraw at any time, and can do so without providing an explanation. If you do withdraw, then your data will not be included in the final analysis.

What will happen to the information when this study is over?

The data will be kept for at least 5 years following completion (publication) of the research. This data will not be identifiable to you. De-identified data will be archived, if you consent.

How will the results of the study be published?

Data will be published in academic peer-reviewed journals. Following publication, links to articles will be available via the UTAS research portal: https://rmdb.research.utas.edu.au/public/rmdb/q/warp_home

What if I have questions about this study?

If you have any questions please contact the lead investigator, Dr Mark Hinder, Mark.Hinder@utas.edu.au, 6226 2945, or ask the investigator who is running the experiment. Other investigators can also be contacted by email (Andrew Heathcote: Andrew.Heathcote@utas.edu.au; Rohan Puri: Rohan.Puri@utas.edu.au; Angus Reynolds: Angus.Reynolds@utas.edu.au; Roderick Garton: Roderick.Garton@utas.edu.au); Elise Yaxley: Yaxleye@utas.edu.au

This study has been approved by the Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on +61 3 6226 6254 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number H0016981."

Should you wish to participate, you may keep this information sheet for your records; you will also be asked to sign a consent form. Thank you.

Appendix D: Consent Form

UTAS

School of Psychology

Informed Consent Form – Behavioural Testing

1. I have read and understood the Information Sheet for this study.
2. I understand that this experimental session will last no more than 2 1⁄2 hours and that I may have been asked to undertake multiple sessions.
3. I understand that I will receive course credit for the total time that I am involved in the study, or will be eligible for a voucher to compensate me for time/travel costs.
4. I understand that all research data will be securely stored on the University of Tasmania premises for a period of 5 years. Electronic data will be stored on a password protected computer. All data will be destroyed at the end of 5 years.
5. Any questions that I have asked have been answered to my satisfaction.
6. I agree that research data gathered for the study may be published provided that I cannot be identified as a subject.
7. I agree to participate in this investigation and understand that I may withdraw at any time without any effect. Following completion of the experiment, please contact a researcher if you wish to have your data withdrawn from the study for any reason. Data can be withdrawn at any time until submission of the manuscripts for publication (~ 6-12 months following completion of data collection).

Name of Participant: ____ Signature of Participant: ________________________________Date:_____________

I have explained this project and the implications of participation in it to this participant, and I believe that the consent is informed and that he/she understands the implications of participation.

Name of Investigator: ____ Signature of Investigator: _______________________________Date:_____________

Appendix E: Ethics Approval Letter

From: Social Sciences Ethics

Sent: Monday, 9 April 2018 4:03 PM

To: Mark Hinder <mark.hinder@utas.edu.au>

Cc: Andrew Heathcote <andrew.heathcote@utas.edu.au>; Tess Nikitenko <tess.nikitenko@utas.edu.au>; Roderick Garton <roderick.garton@utas.edu.au>; Rohan Puri <rohan.puri@utas.edu.au>; Angus Reynolds <angus.reynolds@utas.edu.au>; Elise Yaxley <yaxleye@utas.edu.au>; Social Sciences Ethics <ss.ethics@utas.edu.au>

Subject: H0016981 Understanding the influence of cognitive processing and brain connectivity on rapid motor responses across the lifespan: A model-based neuroscience approach

Dear Dr Hinder

Ethics Ref: H0016981
Title: Understanding the influence of cognitive processing and brain connectivity on rapid motor responses across the lifespan: A model-based neuroscience approach

This email is to confirm that the following amendment was approved by the Chair of the Tasmania Social Sciences Human Research Ethics Committee on 9/4/2018:

- To add Elise Yaxley as a student researcher – could you please provide the following information and email ss.ethics@utas.edu.au so we are able to add Elise to our database
  - DOB
  - Organisation /school
  - Contact details
  - Current study level: Honours / Master/ PhD

All committees operating under the Human Research Ethics Committee (Tasmania) Network are registered and required to comply with the National Statement on Ethical Conduct in Human Research (NHMRC 2007, updated May 2015).

This email constitutes official approval. If your circumstances require a formal letter of amendment approval, please let us know.

Should you have any queries please do not hesitate to contact ss.ethics@utas.edu.au

Kind regards
Jude

Jude Vienna-Hallam

Ethics Administration Officer

Research Integrity and Ethics Unit / Research Division

University of Tasmania

Building 1, 1st Floor, 301 Sandy Bay Road

Hobart TAS 7001

+61 3 6226 2608

www.utas.edu.au/research-admin/reasearch-integrity-and-ethics-unit-rieu

<image001.png>

CRICOS 00586B

Appendix F: SPSS Output

Stop Success

Reactive		Proactive	
Left Stop Success	Right Stop Success	Left Stop Success	Right Stop Success
42	46	46	47
32	44	44	39
53	50	50	53
49	48	48	48
50	49	49	50
48	50	50	48
51	51	51	53
51	53	53	52
47	51	51	49
48	51	51	53
51	51	51	51
47	47	47	47
47	50	50	49
55	55	55	55
28	33	33	36
46	49	49	50
46	46	46	52
50	48	48	46
53	52	52	53
44	52	52	51
47	52	52	50
49	49	49	51
48	48	48	50
44	50	50	49
48	51	51	51
50	49	49	50
48	48	48	48
49	48	48	49
50	49	49	49
49	51	51	51
52	53	53	53
50	53	53	53
45	51	51	50
49	49	49	47
51	54	54	54
36	44	44	46
47	49	49	50

Bimanual Go Reaction Time

Descriptive Statistics

	Handedness_L1_R2	CueType_S1_W2	Mean	Std. Deviation	N
RE_BiGoRT_L	1	1	459.50	145.732	8
		2	467.57	106.588	7
		Total	463.27	124.520	15
	2	1	485.91	161.415	11
		2	405.70	100.260	10
		Total	447.71	138.693	21
	Total	1	474.79	151.372	19
		2	431.18	104.402	17
		Total	454.19	131.356	36
RE_BiGoRT_R	1	1	462.88	147.031	8
		2	467.00	112.951	7
		Total	464.80	127.598	15
	2	1	482.73	164.581	11
		2	400.50	100.289	10
		Total	443.57	140.855	21
	Total	1	474.37	153.482	19
		2	427.88	107.610	17
		Total	452.42	134.024	36
PRO_BiGoRT_L	1	1	487.50	144.833	8
		2	520.86	120.114	7
		Total	503.07	130.262	15
	2	1	511.91	160.229	11
		2	429.50	106.972	10
		Total	472.67	140.587	21
	Total	1	501.63	150.246	19
		2	467.12	118.300	17
		Total	485.33	135.324	36
PRO_BiGoRT_R	1	1	490.63	143.753	8
		2	522.71	121.257	7
		Total	505.60	130.032	15
	2	1	509.27	162.617	11
		2	425.60	108.690	10
		Total	469.43	142.730	21
	Total	1	501.42	151.053	19
		2	465.59	120.773	17
		Total	484.50	136.863	36

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Condition	1.000	.000	0	.	1.000	1.000	1.000
Hand	1.000	.000	0	.	1.000	1.000	1.000
Condition * Hand	1.000	.000	0	.	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Condition	Sphericity Assumed	38614.4	1	38614.4	6.694	.014	.173
	Greenhouse-Geisser	38614.4	1.000	38614.4	6.694	.014	.173
	Huynh-Feldt	38614.4	1.000	38614.4	6.694	.014	.173
	Lower-bound	38614.4	1.000	38614.4	6.694	.014	.173
Condition * Handedness_L1_R2	Sphericity Assumed	2183.83	1	2183.83	.379	.543	.012
	Greenhouse-Geisser	2183.83	1.000	2183.83	.379	.543	.012
	Huynh-Feldt	2183.83	1.000	2183.83	.379	.543	.012
	Lower-bound	2183.83	1.000	2183.83	.379	.543	.012
Condition * CueType_S1_W2	Sphericity Assumed	1340.88	1	1340.88	.232	.633	.007
	Greenhouse-Geisser	1340.88	1.000	1340.88	.232	.633	.007
	Huynh-Feldt	1340.88	1.000	1340.88	.232	.633	.007
	Lower-bound	1340.88	1.000	1340.88	.232	.633	.007
Condition * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	1764.02	1	1764.02	.306	.584	.009
	Greenhouse-Geisser	1764.02	1.000	1764.02	.306	.584	.009
	Huynh-Feldt	1764.02	1.000	1764.02	.306	.584	.009
	Lower-bound	1764.02	1.000	1764.02	.306	.584	.009
Error(Condition)	Sphericity Assumed	184585	32	5768.27			
	Greenhouse-Geisser	184585	32.000	5768.27			
	Huynh-Feldt	184585	32.000	5768.27			
	Lower-bound	184585	32.000	5768.27			
Hand	Sphericity Assumed	27.722	1	27.722	.986	.328	.030
	Greenhouse-Geisser	27.722	1.000	27.722	.986	.328	.030
	Huynh-Feldt	27.722	1.000	27.722	.986	.328	.030
	Lower-bound	27.722	1.000	27.722	.986	.328	.030
Hand * Handedness_L1_R2	Sphericity Assumed	280.898	1	280.898	9.988	.003	.238
	Greenhouse-Geisser	280.898	1.000	280.898	9.988	.003	.238
	Huynh-Feldt	280.898	1.000	280.898	9.988	.003	.238
	Lower-bound	280.898	1.000	280.898	9.988	.003	.238
Hand * CueType_S1_W2	Sphericity Assumed	39.336	1	39.336	1.399	.246	.042
	Greenhouse-Geisser	39.336	1.000	39.336	1.399	.246	.042
	Huynh-Feldt	39.336	1.000	39.336	1.399	.246	.042
	Lower-bound	39.336	1.000	39.336	1.399	.246	.042
Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	2.035	1	2.035	.072	.790	.002
	Greenhouse-Geisser	2.035	1.000	2.035	.072	.790	.002
	Huynh-Feldt	2.035	1.000	2.035	.072	.790	.002
	Lower-bound	2.035	1.000	2.035	.072	.790	.002
Error(Hand)	Sphericity Assumed	899.991	32	28.125			
	Greenhouse-Geisser	899.991	32.000	28.125			
	Huynh-Feldt	899.991	32.000	28.125			
	Lower-bound	899.991	32.000	28.125			
Condition * Hand	Sphericity Assumed	8.824	1	8.824	1.798	.189	.053
	Greenhouse-Geisser	8.824	1.000	8.824	1.798	.189	.053
	Huynh-Feldt	8.824	1.000	8.824	1.798	.189	.053
	Lower-bound	8.824	1.000	8.824	1.798	.189	.053
Condition * Hand * Handedness_L1_R2	Sphericity Assumed	.060	1	.060	.012	.912	.000
	Greenhouse-Geisser	.060	1.000	.060	.012	.912	.000
	Huynh-Feldt	.060	1.000	.060	.012	.912	.000
	Lower-bound	.060	1.000	.060	.012	.912	.000
Condition * Hand * CueType_S1_W2	Sphericity Assumed	6.423	1	6.423	1.309	.261	.039
	Greenhouse-Geisser	6.423	1.000	6.423	1.309	.261	.039
	Huynh-Feldt	6.423	1.000	6.423	1.309	.261	.039
	Lower-bound	6.423	1.000	6.423	1.309	.261	.039
Condition * Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	2.017	1	2.017	.411	.526	.013
	Greenhouse-Geisser	2.017	1.000	2.017	.411	.526	.013
	Huynh-Feldt	2.017	1.000	2.017	.411	.526	.013
	Lower-bound	2.017	1.000	2.017	.411	.526	.013
Error(Condition*Hand)	Sphericity Assumed	157.010	32	4.907			
	Greenhouse-Geisser	157.010	32.000	4.907			
	Huynh-Feldt	157.010	32.000	4.907			
	Lower-bound	157.010	32.000	4.907			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	3.09E+7	1	3.09E+7	455.991	.000	.934
Handedness_L1_R2	28210.2	1	28210.2	.416	.523	.013
CueType_S1_W2	34297.7	1	34297.7	.506	.482	.016
Handedness_L1_R2 * CueType_S1_W2	89897.0	1	89897.0	1.327	.258	.040
Error	2.17E+6	32	67757.1			

Significant main effect of condition type

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	453.973	22.763	407.607	500.339
2	487.247	23.151	440.091	534.404

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-33.27*	12.861	.014	-59.470	-7.078
2	1	33.274*	12.861	.014	7.078	59.470

*Significant handedness *hand*

Measure: MEASURE_1

Handedness_L1_R2	Hand	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	483.857	33.435	415.753	551.961
	2	485.804	33.937	416.676	554.931
2	1	458.255	28.227	400.759	515.750
	2	454.525	28.651	396.165	512.885

Bimanual Go x Fail

Descriptive Statistics

	Handedness_L1_R2	CueType_S1_W2	Mean	Std. Deviation	N
RE_BiGoRT_L	1	1	459.50	145.732	8
		2	467.57	106.588	7
		Total	463.27	124.520	15
	2	1	485.91	161.415	11
		2	405.70	100.260	10
		Total	447.71	138.693	21
	Total	1	474.79	151.372	19
		2	431.18	104.402	17
		Total	454.19	131.356	36
RE_FailedLStop_L	1	1	405.75	123.361	8
		2	403.57	95.278	7
		Total	404.73	107.242	15
	2	1	436.45	146.637	11
		2	359.30	86.038	10
		Total	399.71	125.066	21
	Total	1	423.53	134.560	19
		2	377.53	89.847	17
		Total	401.81	116.381	36
RE_FailedRStop_L	1	1	414.37	133.076	8
		2	420.86	85.807	7
		Total	417.40	109.641	15
	2	1	457.73	152.268	11
		2	371.00	87.530	10
		Total	416.43	130.424	21
	Total	1	439.47	142.307	19
		2	391.53	87.809	17
		Total	416.83	120.536	36
RE_BiGoRT_R	1	1	462.88	147.031	8
		2	467.00	112.951	7
		Total	464.80	127.598	15
	2	1	482.73	164.581	11
		2	400.50	100.289	10
		Total	443.57	140.855	21
	Total	1	474.37	153.482	19
		2	427.88	107.610	17
		Total	452.42	134.024	36
RE_FailedLStop_R	1	1	416.50	128.994	8
		2	426.29	87.407	7
		Total	421.07	107.794	15
	2	1	437.18	152.938	11
		2	367.20	90.459	10
		Total	403.86	129.073	21
	Total	1	428.47	139.912	19
		2	391.53	91.467	17
		Total	411.03	119.339	36
RE_FailedRStop_R	1	1	413.25	132.818	8
		2	420.71	88.136	7
		Total	416.73	110.291	15
	2	1	443.82	160.430	11
		2	356.80	87.412	10
		Total	402.38	135.242	21
	Total	1	430.95	146.285	19
		2	383.12	90.897	17
		Total	408.36	123.971	36
PRO_BiGoRT_L	1	1	487.50	144.833	8
		2	520.86	120.114	7
		Total	503.07	130.262	15
	2	1	511.91	160.229	11
		2	429.50	106.972	10
		Total	472.67	140.587	21
	Total	1	501.63	150.246	19
		2	467.12	118.300	17
		Total	485.33	135.324	36

PRO_FailedRStop_L	1	1	434.88	113.444	8
		2	467.71	104.492	7
		Total	450.20	106.779	15
	2	1	469.91	145.958	11
		2	388.00	94.971	10
		Total	430.90	128.327	21
	Total	1	455.16	130.981	19
		2	420.82	103.939	17
		Total	438.94	118.591	36
PRO_BiGoRT_R	1	1	490.63	143.753	8
		2	522.71	121.257	7
		Total	505.60	130.032	15
	2	1	509.27	162.617	11
		2	425.60	108.690	10
		Total	469.43	142.730	21
	Total	1	501.42	151.053	19
		2	465.59	120.773	17
		Total	484.50	136.863	36
PRO_FailedLStop_R	1	1	443.75	116.378	8
		2	472.14	102.769	7
		Total	457.00	107.300	15
	2	1	464.64	149.081	11
		2	383.90	98.202	10
		Total	426.19	130.994	21
	Total	1	455.84	133.142	19
		2	420.24	106.720	17
		Total	439.03	121.029	36
PRO_FailedRStop_R	1	1	437.88	112.939	8
		2	461.86	109.155	7
		Total	449.07	107.877	15
	2	1	461.09	152.665	11
		2	381.60	101.213	10
		Total	423.24	133.858	21
	Total	1	451.32	134.340	19
		2	414.65	109.032	17
		Total	434.00	122.722	36

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Condition	1.000	.000	0	.	1.000	1.000	1.000
Hand	1.000	.000	0	.	1.000	1.000	1.000
Go_Fail	.728	9.838	2	.007	.786	.897	.500
Condition * Hand	1.000	.000	0	.	1.000	1.000	1.000
Condition * Go_Fail	.983	.517	2	.772	.984	1.000	.500
Hand * Go_Fail	.716	10.343	2	.006	.779	.888	.500
Condition * Hand * Go_Fail	.647	13.475	2	.001	.739	.839	.500

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Condition	Sphericity Assumed	95846.7	1	95846.7	6.026	.020	.158
	Greenhouse-Geisser	95846.7	1.000	95846.7	6.026	.020	.158
	Huynh-Feldt	95846.7	1.000	95846.7	6.026	.020	.158
	Lower-bound	95846.7	1.000	95846.7	6.026	.020	.158
Condition * Handedness_L1_R2	Sphericity Assumed	5548.96	1	5548.96	.349	.559	.011
	Greenhouse-Geisser	5548.96	1.000	5548.96	.349	.559	.011
	Huynh-Feldt	5548.96	1.000	5548.96	.349	.559	.011
	Lower-bound	5548.96	1.000	5548.96	.349	.559	.011
Condition * CueType_S1_W2	Sphericity Assumed	3109.16	1	3109.16	.195	.661	.006
	Greenhouse-Geisser	3109.16	1.000	3109.16	.195	.661	.006
	Huynh-Feldt	3109.16	1.000	3109.16	.195	.661	.006
	Lower-bound	3109.16	1.000	3109.16	.195	.661	.006
Condition * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	3917.11	1	3917.11	.246	.623	.008
	Greenhouse-Geisser	3917.11	1.000	3917.11	.246	.623	.008
	Huynh-Feldt	3917.11	1.000	3917.11	.246	.623	.008
	Lower-bound	3917.11	1.000	3917.11	.246	.623	.008
Error(Condition)	Sphericity Assumed	508977	32	15905.5			
	Greenhouse-Geisser	508977	32.000	15905.5			
	Huynh-Feldt	508977	32.000	15905.5			
	Lower-bound	508977	32.000	15905.5			
Hand	Sphericity Assumed	12.509	1	12.509	.049	.826	.002
	Greenhouse-Geisser	12.509	1.000	12.509	.049	.826	.002
	Huynh-Feldt	12.509	1.000	12.509	.049	.826	.002
	Lower-bound	12.509	1.000	12.509	.049	.826	.002
Hand * Handedness_L1_R2	Sphericity Assumed	2610.49	1	2610.49	10.238	.003	.242
	Greenhouse-Geisser	2610.49	1.000	2610.49	10.238	.003	.242
	Huynh-Feldt	2610.49	1.000	2610.49	10.238	.003	.242
	Lower-bound	2610.49	1.000	2610.49	10.238	.003	.242
Hand * CueType_S1_W2	Sphericity Assumed	34.244	1	34.244	.134	.716	.004
	Greenhouse-Geisser	34.244	1.000	34.244	.134	.716	.004
	Huynh-Feldt	34.244	1.000	34.244	.134	.716	.004
	Lower-bound	34.244	1.000	34.244	.134	.716	.004
Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	1.692	1	1.692	.007	.936	.000
	Greenhouse-Geisser	1.692	1.000	1.692	.007	.936	.000
	Huynh-Feldt	1.692	1.000	1.692	.007	.936	.000
	Lower-bound	1.692	1.000	1.692	.007	.936	.000
Error(Hand)	Sphericity Assumed	8159.36	32	254.980			
	Greenhouse-Geisser	8159.36	32.000	254.980			
	Huynh-Feldt	8159.36	32.000	254.980			
	Lower-bound	8159.36	32.000	254.980			
Go_Fail	Sphericity Assumed	204201	2	102100	104.027	.000	.765
	Greenhouse-Geisser	204201	1.572	129863	104.027	.000	.765
	Huynh-Feldt	204201	1.795	113782	104.027	.000	.765
	Lower-bound	204201	1.000	204201	104.027	.000	.765
Go_Fail * Handedness_L1_R2	Sphericity Assumed	2362.12	2	1181.06	1.203	.307	.036
	Greenhouse-Geisser	2362.12	1.572	1502.21	1.203	.300	.036
	Huynh-Feldt	2362.12	1.795	1316.18	1.203	.304	.036
	Lower-bound	2362.12	1.000	2362.12	1.203	.281	.036
Go_Fail * CueType_S1_W2	Sphericity Assumed	57.272	2	28.636	.029	.971	.001
	Greenhouse-Geisser	57.272	1.572	36.423	.029	.945	.001
	Huynh-Feldt	57.272	1.795	31.912	.029	.961	.001
	Lower-bound	57.272	1.000	57.272	.029	.865	.001
Go_Fail * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	500.779	2	250.390	.255	.776	.008
	Greenhouse-Geisser	500.779	1.572	318.475	.255	.722	.008
	Huynh-Feldt	500.779	1.795	279.037	.255	.752	.008
	Lower-bound	500.779	1.000	500.779	.255	.617	.008
Error(Go_Fail)	Sphericity Assumed	62814.9	64	981.483			
	Greenhouse-Geisser	62814.9	50.318	1248.37			
	Huynh-Feldt	62814.9	57.429	1093.78			
	Lower-bound	62814.9	32.000	1962.97			
Condition * Hand	Sphericity Assumed	6.483	1	6.483	.105	.748	.003
	Greenhouse-Geisser	6.483	1.000	6.483	.105	.748	.003
	Huynh-Feldt	6.483	1.000	6.483	.105	.748	.003
	Lower-bound	6.483	1.000	6.483	.105	.748	.003
Condition * Hand * Handedness_L1_R2	Sphericity Assumed	6.210	1	6.210	.101	.753	.003
	Greenhouse-Geisser	6.210	1.000	6.210	.101	.753	.003
	Huynh-Feldt	6.210	1.000	6.210	.101	.753	.003
	Lower-bound	6.210	1.000	6.210	.101	.753	.003

Condition * Hand	Sphericity Assumed	6.483	1	6.483	.105	.748	.003
	Greenhouse-Geisser	6.483	1.000	6.483	.105	.748	.003
	Huynh-Feldt	6.483	1.000	6.483	.105	.748	.003
	Lower-bound	6.483	1.000	6.483	.105	.748	.003
Condition * Hand * Handedness_L1_R2	Sphericity Assumed	6.210	1	6.210	.101	.753	.003
	Greenhouse-Geisser	6.210	1.000	6.210	.101	.753	.003
	Huynh-Feldt	6.210	1.000	6.210	.101	.753	.003
	Lower-bound	6.210	1.000	6.210	.101	.753	.003
Condition * Hand * CueType_S1_W2	Sphericity Assumed	35.588	1	35.588	.578	.453	.018
	Greenhouse-Geisser	35.588	1.000	35.588	.578	.453	.018
	Huynh-Feldt	35.588	1.000	35.588	.578	.453	.018
	Lower-bound	35.588	1.000	35.588	.578	.453	.018
Condition * Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	23.295	1	23.295	.378	.543	.012
	Greenhouse-Geisser	23.295	1.000	23.295	.378	.543	.012
	Huynh-Feldt	23.295	1.000	23.295	.378	.543	.012
	Lower-bound	23.295	1.000	23.295	.378	.543	.012
Error(Condition*Hand)	Sphericity Assumed	1971.66	32	61.614			
	Greenhouse-Geisser	1971.66	32.000	61.614			
	Huynh-Feldt	1971.66	32.000	61.614			
	Lower-bound	1971.66	32.000	61.614			
Condition * Go_Fail	Sphericity Assumed	1194.37	2	597.186	1.908	.157	.056
	Greenhouse-Geisser	1194.37	1.967	607.055	1.908	.158	.056
	Huynh-Feldt	1194.37	2.000	597.186	1.908	.157	.056
	Lower-bound	1194.37	1.000	1194.37	1.908	.177	.056
Condition * Go_Fail * Handedness_L1_R2	Sphericity Assumed	61.790	2	30.895	.099	.906	.003
	Greenhouse-Geisser	61.790	1.967	31.406	.099	.903	.003
	Huynh-Feldt	61.790	2.000	30.895	.099	.906	.003
	Lower-bound	61.790	1.000	61.790	.099	.755	.003
Condition * Go_Fail * CueType_S1_W2	Sphericity Assumed	261.934	2	130.967	.418	.660	.013
	Greenhouse-Geisser	261.934	1.967	133.131	.418	.657	.013
	Huynh-Feldt	261.934	2.000	130.967	.418	.660	.013
	Lower-bound	261.934	1.000	261.934	.418	.522	.013
Condition * Go_Fail * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	279.083	2	139.541	.446	.642	.014
	Greenhouse-Geisser	279.083	1.967	141.847	.446	.639	.014
	Huynh-Feldt	279.083	2.000	139.541	.446	.642	.014
	Lower-bound	279.083	1.000	279.083	.446	.509	.014
Error(Condition*Go_Fail)	Sphericity Assumed	20035.6	64	313.056			
	Greenhouse-Geisser	20035.6	62.960	318.229			
	Huynh-Feldt	20035.6	64.000	313.056			
	Lower-bound	20035.6	32.000	626.111			
Hand * Go_Fail	Sphericity Assumed	3397.11	2	1698.56	18.478	.000	.366
	Greenhouse-Geisser	3397.11	1.558	2180.41	18.478	.000	.366
	Huynh-Feldt	3397.11	1.777	1911.95	18.478	.000	.366
	Lower-bound	3397.11	1.000	3397.11	18.478	.000	.366
Hand * Go_Fail * Handedness_L1_R2	Sphericity Assumed	339.417	2	169.709	1.846	.166	.055
	Greenhouse-Geisser	339.417	1.558	217.852	1.846	.176	.055
	Huynh-Feldt	339.417	1.777	191.029	1.846	.171	.055
	Lower-bound	339.417	1.000	339.417	1.846	.184	.055
Hand * Go_Fail * CueType_S1_W2	Sphericity Assumed	449.536	2	224.768	2.445	.095	.071
	Greenhouse-Geisser	449.536	1.558	288.530	2.445	.109	.071
	Huynh-Feldt	449.536	1.777	253.006	2.445	.102	.071
	Lower-bound	449.536	1.000	449.536	2.445	.128	.071
Hand * Go_Fail * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	97.863	2	48.932	.532	.590	.016
	Greenhouse-Geisser	97.863	1.558	62.813	.532	.546	.016
	Huynh-Feldt	97.863	1.777	55.079	.532	.569	.016
	Lower-bound	97.863	1.000	97.863	.532	.471	.016
Error(Hand*Go_Fail)	Sphericity Assumed	5883.11	64	91.924			
	Greenhouse-Geisser	5883.11	49.857	118.001			
	Huynh-Feldt	5883.11	56.857	103.472			
	Lower-bound	5883.11	32.000	183.847			
Condition * Hand * Go_Fail	Sphericity Assumed	319.178	2	159.589	3.341	.042	.095
	Greenhouse-Geisser	319.178	1.479	215.849	3.341	.058	.095
	Huynh-Feldt	319.178	1.679	190.143	3.341	.051	.095
	Lower-bound	319.178	1.000	319.178	3.341	.077	.095
Condition * Hand * Go_Fail * Handedness_L1_R2	Sphericity Assumed	145.652	2	72.826	1.524	.226	.045
	Greenhouse-Geisser	145.652	1.479	98.499	1.524	.229	.045
	Huynh-Feldt	145.652	1.679	86.769	1.524	.228	.045
	Lower-bound	145.652	1.000	145.652	1.524	.226	.045
Condition * Hand * Go_Fail * CueType_S1_W2	Sphericity Assumed	56.352	2	28.176	.590	.557	.018
	Greenhouse-Geisser	56.352	1.479	38.109	.590	.509	.018
	Huynh-Feldt	56.352	1.679	33.571	.590	.529	.018
	Lower-bound	56.352	1.000	56.352	.590	.448	.018
Condition * Hand * Go_Fail * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	64.797	2	32.398	.678	.511	.021
	Greenhouse-Geisser	64.797	1.479	43.820	.678	.470	.021
	Huynh-Feldt	64.797	1.679	38.601	.678	.487	.021
	Lower-bound	64.797	1.000	64.797	.678	.416	.021
Error(Condition*Hand*Go_Fail)	Sphericity Assumed	3057.45	64	47.773			
	Greenhouse-Geisser	3057.45	47.319	64.614			
	Huynh-Feldt	3057.45	53.716	56.919			
	Lower-bound	3057.45	32.000	95.545			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	8.08E+7	1	8.08E+7	471.830	.000	.936
Handedness_L1_R2	49618.0	1	49618.0	.290	.594	.009
CueType_S1_W2	107225	1	107225	.626	.435	.019
Handedness_L1_R2 * CueType_S1_W2	253347	1	253347	1.479	.233	.044
Error	5.48E+6	32	171261			

Main effect of Bi_Go

Estimates

Measure: MEASURE_1

Go_Fail	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	470.610	22.039	425.719	515.501
2	422.519	19.269	383.270	461.769
3	425.091	19.614	385.139	465.044

Pairwise Comparisons

Measure: MEASURE_1

(I) Go_Fail	(J) Go_Fail	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	95% Confidence Interval for Difference[b] Upper Bound
1	2	48.091*	4.475	.000	36.785	59.396
	3	45.519*	3.848	.000	35.796	55.241
2	1	-48.09*	4.475	.000	-59.396	-36.785
	3	-2.572	2.717	1.000	-9.435	4.291
3	1	-45.52*	3.848	.000	-55.241	-35.796
	2	2.572	2.717	1.000	-4.291	9.435

Selective Stop Cost

Descriptive Statistics

	Handedness_L1_R2	CueType_S1_W2	Mean	Std. Deviation	N
RE_SSC_L	1	1	76.50	18.616	8
		2	90.71	45.228	7
		Total	83.13	33.224	15
	2	1	95.00	25.282	11
		2	98.60	29.845	10
		Total	96.71	26.904	21
	Total	1	87.21	24.041	19
		2	95.35	35.835	17
		Total	91.06	30.021	36
RE_SSC_R	1	1	81.75	22.493	8
		2	85.57	20.598	7
		Total	83.53	20.945	15
	2	1	94.91	23.793	11
		2	102.80	27.324	10
		Total	98.67	25.206	21
	Total	1	89.37	23.575	19
		2	95.71	25.602	17
		Total	92.36	24.409	36
PRO_SSC_L	1	1	48.13	34.836	8
		2	65.00	37.917	7
		Total	56.00	36.040	15
	2	1	79.55	32.101	11
		2	60.40	37.239	10
		Total	70.43	35.146	21
	Total	1	66.32	36.034	19
		2	62.29	36.395	17
		Total	64.42	35.741	36
PRO_SSC_R	1	1	43.75	38.975	8
		2	65.43	35.711	7
		Total	53.87	37.834	15
	2	1	66.45	28.098	11
		2	63.70	28.523	10
		Total	65.14	27.619	21
	Total	1	56.89	34.088	19
		2	64.41	30.604	17
		Total	60.44	32.253	36

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Condition	1.000	.000	0	.	1.000	1.000	1.000
Hand	1.000	.000	0	.	1.000	1.000	1.000
Condition * Hand	1.000	.000	0	.	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Condition	Sphericity Assumed	29696.4	1	29696.4	44.618	.000	.582
	Greenhouse-Geisser	29696.4	1.000	29696.4	44.618	.000	.582
	Huynh-Feldt	29696.4	1.000	29696.4	44.618	.000	.582
	Lower-bound	29696.4	1.000	29696.4	44.618	.000	.582
Condition * Handedness_L1_R2	Sphericity Assumed	43.914	1	43.914	.066	.799	.002
	Greenhouse-Geisser	43.914	1.000	43.914	.066	.799	.002
	Huynh-Feldt	43.914	1.000	43.914	.066	.799	.002
	Lower-bound	43.914	1.000	43.914	.066	.799	.002
Condition * CueType_S1_W2	Sphericity Assumed	90.305	1	90.305	.136	.715	.004
	Greenhouse-Geisser	90.305	1.000	90.305	.136	.715	.004
	Huynh-Feldt	90.305	1.000	90.305	.136	.715	.004
	Lower-bound	90.305	1.000	90.305	.136	.715	.004
Condition * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	1583.68	1	1583.68	2.379	.133	.069
	Greenhouse-Geisser	1583.68	1.000	1583.68	2.379	.133	.069
	Huynh-Feldt	1583.68	1.000	1583.68	2.379	.133	.069
	Lower-bound	1583.68	1.000	1583.68	2.379	.133	.069
Error(Condition)	Sphericity Assumed	21298.4	32	665.576			
	Greenhouse-Geisser	21298.4	32.000	665.576			
	Huynh-Feldt	21298.4	32.000	665.576			
	Lower-bound	21298.4	32.000	665.576			
Hand	Sphericity Assumed	49.400	1	49.400	.122	.729	.004
	Greenhouse-Geisser	49.400	1.000	49.400	.122	.729	.004
	Huynh-Feldt	49.400	1.000	49.400	.122	.729	.004
	Lower-bound	49.400	1.000	49.400	.122	.729	.004
Hand * Handedness_L1_R2	Sphericity Assumed	1.850	1	1.850	.005	.946	.000
	Greenhouse-Geisser	1.850	1.000	1.850	.005	.946	.000
	Huynh-Feldt	1.850	1.000	1.850	.005	.946	.000
	Lower-bound	1.850	1.000	1.850	.005	.946	.000
Hand * CueType_S1_W2	Sphericity Assumed	124.129	1	124.129	.308	.583	.010
	Greenhouse-Geisser	124.129	1.000	124.129	.308	.583	.010
	Huynh-Feldt	124.129	1.000	124.129	.308	.583	.010
	Lower-bound	124.129	1.000	124.129	.308	.583	.010
Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	376.102	1	376.102	.932	.342	.028
	Greenhouse-Geisser	376.102	1.000	376.102	.932	.342	.028
	Huynh-Feldt	376.102	1.000	376.102	.932	.342	.028
	Lower-bound	376.102	1.000	376.102	.932	.342	.028
Error(Hand)	Sphericity Assumed	12909.1	32	403.410			
	Greenhouse-Geisser	12909.1	32.000	403.410			
	Huynh-Feldt	12909.1	32.000	403.410			
	Lower-bound	12909.1	32.000	403.410			
Condition * Hand	Sphericity Assumed	175.651	1	175.651	.558	.460	.017
	Greenhouse-Geisser	175.651	1.000	175.651	.558	.460	.017
	Huynh-Feldt	175.651	1.000	175.651	.558	.460	.017
	Lower-bound	175.651	1.000	175.651	.558	.460	.017
Condition * Hand * Handedness_L1_R2	Sphericity Assumed	52.833	1	52.833	.168	.685	.005
	Greenhouse-Geisser	52.833	1.000	52.833	.168	.685	.005
	Huynh-Feldt	52.833	1.000	52.833	.168	.685	.005
	Lower-bound	52.833	1.000	52.833	.168	.685	.005
Condition * Hand * CueType_S1_W2	Sphericity Assumed	406.032	1	406.032	1.291	.264	.039
	Greenhouse-Geisser	406.032	1.000	406.032	1.291	.264	.039
	Huynh-Feldt	406.032	1.000	406.032	1.291	.264	.039
	Lower-bound	406.032	1.000	406.032	1.291	.264	.039
Condition * Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	5.225	1	5.225	.017	.898	.001
	Greenhouse-Geisser	5.225	1.000	5.225	.017	.898	.001
	Huynh-Feldt	5.225	1.000	5.225	.017	.898	.001
	Lower-bound	5.225	1.000	5.225	.017	.898	.001
Error(Condition*Hand)	Sphericity Assumed	10065.6	32	314.551			
	Greenhouse-Geisser	10065.6	32.000	314.551			
	Huynh-Feldt	10065.6	32.000	314.551			
	Lower-bound	10065.6	32.000	314.551			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	808761	1	808761	337.377	.000	.913
Handedness_L1_R2	5958.83	1	5958.83	2.486	.125	.072
CueType_S1_W2	1162.14	1	1162.14	.485	.491	.015
Handedness_L1_R2 * CueType_S1_W2	2446.12	1	2446.12	1.020	.320	.031
Error	76710.4	32	2397.20			

Significant main effect of condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	90.731	3.854	82.881	98.580
2	61.550	5.391	50.570	72.531

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	29.180*	4.369	.000	20.282	38.079
2	1	-29.18*	4.369	.000	-38.079	-20.282

Stop Signal Reaction Time

Descriptive Statistics

	Handedness_L1_R2	CueType_S1_W2	Mean	Std. Deviation	N
RE_SSRT_L	1	1	199.248	20.1226	8
		2	203.051	30.6484	7
		Total	201.023	24.6756	15
	2	1	211.613	24.8764	11
		2	194.370	23.7886	10
		Total	203.402	25.3365	21
	Total	1	206.406	23.2509	19
		2	197.944	26.2671	17
		Total	202.410	24.7344	36
RE_SSRT_R	1	1	196.104	16.9536	8
		2	179.610	46.4216	7
		Total	188.407	33.7611	15
	2	1	209.511	31.7726	11
		2	192.340	28.2901	10
		Total	201.335	30.6939	21
	Total	1	203.866	26.8116	19
		2	187.098	36.0556	17
		Total	195.948	32.1879	36
PRO_SSRT_L	1	1	187.162	32.5815	8
		2	189.990	10.4663	7
		Total	188.482	24.0802	15
	2	1	205.488	41.6286	11
		2	197.436	30.2133	10
		Total	201.654	35.9754	21
	Total	1	197.772	38.2359	19
		2	194.370	23.8500	17
		Total	196.165	31.8571	36
PRO_SSRT_R	1	1	196.960	25.3480	8
		2	195.160	38.6649	7
		Total	196.120	31.0295	15
	2	1	213.326	31.8420	11
		2	199.916	20.5522	10
		Total	206.940	27.2788	21
	Total	1	206.435	29.6998	19
		2	197.958	28.3555	17
		Total	202.432	28.9762	36

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Condition	1.000	.000	0	.	1.000	1.000	1.000
Hand	1.000	.000	0	.	1.000	1.000	1.000
Condition * Hand	1.000	.000	0	.	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Condition	Sphericity Assumed	.091	1	.091	.000	.990	.000
	Greenhouse-Geisser	.091	1.000	.091	.000	.990	.000
	Huynh-Feldt	.091	1.000	.091	.000	.990	.000
	Lower-bound	.091	1.000	.091	.000	.990	.000
Condition * Handedness_L1_R2	Sphericity Assumed	158.830	1	158.830	.289	.595	.009
	Greenhouse-Geisser	158.830	1.000	158.830	.289	.595	.009
	Huynh-Feldt	158.830	1.000	158.830	.289	.595	.009
	Lower-bound	158.830	1.000	158.830	.289	.595	.009
Condition * CueType_S1_W2	Sphericity Assumed	387.634	1	387.634	.705	.407	.022
	Greenhouse-Geisser	387.634	1.000	387.634	.705	.407	.022
	Huynh-Feldt	387.634	1.000	387.634	.705	.407	.022
	Lower-bound	387.634	1.000	387.634	.705	.407	.022
Condition * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	.320	1	.320	.001	.981	.000
	Greenhouse-Geisser	.320	1.000	.320	.001	.981	.000
	Huynh-Feldt	.320	1.000	.320	.001	.981	.000
	Lower-bound	.320	1.000	.320	.001	.981	.000
Error(Condition)	Sphericity Assumed	17601.9	32	550.059			
	Greenhouse-Geisser	17601.9	32.000	550.059			
	Huynh-Feldt	17601.9	32.000	550.059			
	Lower-bound	17601.9	32.000	550.059			
Hand	Sphericity Assumed	16.067	1	16.067	.065	.801	.002
	Greenhouse-Geisser	16.067	1.000	16.067	.065	.801	.002
	Huynh-Feldt	16.067	1.000	16.067	.065	.801	.002
	Lower-bound	16.067	1.000	16.067	.065	.801	.002
Hand * Handedness_L1_R2	Sphericity Assumed	172.749	1	172.749	.696	.410	.021
	Greenhouse-Geisser	172.749	1.000	172.749	.696	.410	.021
	Huynh-Feldt	172.749	1.000	172.749	.696	.410	.021
	Lower-bound	172.749	1.000	172.749	.696	.410	.021
Hand * CueType_S1_W2	Sphericity Assumed	497.398	1	497.398	2.005	.166	.059
	Greenhouse-Geisser	497.398	1.000	497.398	2.005	.166	.059
	Huynh-Feldt	497.398	1.000	497.398	2.005	.166	.059
	Lower-bound	497.398	1.000	497.398	2.005	.166	.059
Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	210.167	1	210.167	.847	.364	.026
	Greenhouse-Geisser	210.167	1.000	210.167	.847	.364	.026
	Huynh-Feldt	210.167	1.000	210.167	.847	.364	.026
	Lower-bound	210.167	1.000	210.167	.847	.364	.026
Error(Hand)	Sphericity Assumed	7937.91	32	248.060			
	Greenhouse-Geisser	7937.91	32.000	248.060			
	Huynh-Feldt	7937.91	32.000	248.060			
	Lower-bound	7937.91	32.000	248.060			
Condition * Hand	Sphericity Assumed	1708.99	1	1708.99	8.296	.007	.206
	Greenhouse-Geisser	1708.99	1.000	1708.99	8.296	.007	.206
	Huynh-Feldt	1708.99	1.000	1708.99	8.296	.007	.206
	Lower-bound	1708.99	1.000	1708.99	8.296	.007	.206
Condition * Hand * Handedness_L1_R2	Sphericity Assumed	400.337	1	400.337	1.943	.173	.057
	Greenhouse-Geisser	400.337	1.000	400.337	1.943	.173	.057
	Huynh-Feldt	400.337	1.000	400.337	1.943	.173	.057
	Lower-bound	400.337	1.000	400.337	1.943	.173	.057
Condition * Hand * CueType_S1_W2	Sphericity Assumed	57.112	1	57.112	.277	.602	.009
	Greenhouse-Geisser	57.112	1.000	57.112	.277	.602	.009
	Huynh-Feldt	57.112	1.000	57.112	.277	.602	.009
	Lower-bound	57.112	1.000	57.112	.277	.602	.009
Condition * Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	242.590	1	242.590	1.178	.286	.035
	Greenhouse-Geisser	242.590	1.000	242.590	1.178	.286	.035
	Huynh-Feldt	242.590	1.000	242.590	1.178	.286	.035
	Lower-bound	242.590	1.000	242.590	1.178	.286	.035
Error(Condition*Hand)	Sphericity Assumed	6592.13	32	206.004			
	Greenhouse-Geisser	6592.13	32.000	206.004			
	Huynh-Feldt	6592.13	32.000	206.004			
	Lower-bound	6592.13	32.000	206.004			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	5.48E+6	1	5.48E+6	2167.78	.000	.985
Handedness_L1_R2	3207.08	1	3207.08	1.269	.268	.038
CueType_S1_W2	2485.66	1	2485.66	.983	.329	.030
Handedness_L1_R2 * CueType_S1_W2	1065.26	1	1065.26	.421	.521	.013
Error	80900.9	32	2528.15			

*Significant condition*hand*

11. Condition * Hand

Measure: MEASURE_1

Condition	Hand	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1	202.070	4.207	193.501	210.639
	2	194.391	5.375	183.443	205.339
2	1	195.019	5.490	183.837	206.201
	2	201.340	4.956	191.246	211.435

Electromyography

Descriptive Statistics

	Handedness_L1_R2	CueType_S1_W2	Mean	Std. Deviation	N
RE_L	1	1	27.24	17.564	8
		2	19.10	10.428	7
		Total	23.44	14.782	15
	2	1	16.15	9.314	11
		2	14.70	15.763	11
		Total	15.43	12.656	22
	Total	1	20.82	14.134	19
		2	16.41	13.762	18
		Total	18.68	13.940	37
RE_R	1	1	32.66	26.616	8
		2	22.94	15.295	7
		Total	28.13	21.901	15
	2	1	23.62	21.447	11
		2	28.83	24.923	11
		Total	26.22	22.846	22
	Total	1	27.43	23.497	19
		2	26.54	21.369	18
		Total	26.99	22.179	37
PRO_L	1	1	11.99	9.916	8
		2	21.59	15.418	7
		Total	16.47	13.252	15
	2	1	12.15	6.941	11
		2	15.25	16.955	11
		Total	13.70	12.741	22
	Total	1	12.08	8.063	19
		2	17.71	16.221	18
		Total	14.82	12.841	37
PRO_R	1	1	26.88	16.018	8
		2	25.49	16.702	7
		Total	26.23	15.759	15
	2	1	29.72	24.402	11
		2	18.41	11.575	11
		Total	24.06	19.515	22
	Total	1	28.52	20.801	19
		2	21.16	13.779	18
		Total	24.94	17.886	37

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Epsilon[b] Huynh-Feldt	Epsilon[b] Lower-bound
Condition	1.000	.000	0	.	1.000	1.000	1.000
Hand	1.000	.000	0	.	1.000	1.000	1.000
Condition * Hand	1.000	.000	0	.	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Condition	Sphericity Assumed	314.431	1	314.431	1.813	.187	.052
	Greenhouse-Geisser	314.431	1.000	314.431	1.813	.187	.052
	Huynh-Feldt	314.431	1.000	314.431	1.813	.187	.052
	Lower-bound	314.431	1.000	314.431	1.813	.187	.052
Condition * Handedness_L1_R2	Sphericity Assumed	37.713	1	37.713	.217	.644	.007
	Greenhouse-Geisser	37.713	1.000	37.713	.217	.644	.007
	Huynh-Feldt	37.713	1.000	37.713	.217	.644	.007
	Lower-bound	37.713	1.000	37.713	.217	.644	.007
Condition * CueType_S1_W2	Sphericity Assumed	110.425	1	110.425	.637	.431	.019
	Greenhouse-Geisser	110.425	1.000	110.425	.637	.431	.019
	Huynh-Feldt	110.425	1.000	110.425	.637	.431	.019
	Lower-bound	110.425	1.000	110.425	.637	.431	.019
Condition * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	804.442	1	804.442	4.638	.039	.123
	Greenhouse-Geisser	804.442	1.000	804.442	4.638	.039	.123
	Huynh-Feldt	804.442	1.000	804.442	4.638	.039	.123
	Lower-bound	804.442	1.000	804.442	4.638	.039	.123
Error(Condition)	Sphericity Assumed	5723.86	33	173.450			
	Greenhouse-Geisser	5723.86	33.000	173.450			
	Huynh-Feldt	5723.86	33.000	173.450			
	Lower-bound	5723.86	33.000	173.450			
Hand	Sphericity Assumed	2753.34	1	2753.34	8.598	.006	.207
	Greenhouse-Geisser	2753.34	1.000	2753.34	8.598	.006	.207
	Huynh-Feldt	2753.34	1.000	2753.34	8.598	.006	.207
	Lower-bound	2753.34	1.000	2753.34	8.598	.006	.207
Hand * Handedness_L1_R2	Sphericity Assumed	113.097	1	113.097	.353	.556	.011
	Greenhouse-Geisser	113.097	1.000	113.097	.353	.556	.011
	Huynh-Feldt	113.097	1.000	113.097	.353	.556	.011
	Lower-bound	113.097	1.000	113.097	.353	.556	.011
Hand * CueType_S1_W2	Sphericity Assumed	229.240	1	229.240	.716	.404	.021
	Greenhouse-Geisser	229.240	1.000	229.240	.716	.404	.021
	Huynh-Feldt	229.240	1.000	229.240	.716	.404	.021
	Lower-bound	229.240	1.000	229.240	.716	.404	.021
Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	12.987	1	12.987	.041	.842	.001
	Greenhouse-Geisser	12.987	1.000	12.987	.041	.842	.001
	Huynh-Feldt	12.987	1.000	12.987	.041	.842	.001
	Lower-bound	12.987	1.000	12.987	.041	.842	.001
Error(Hand)	Sphericity Assumed	10567.0	33	320.212			
	Greenhouse-Geisser	10567.0	33.000	320.212			
	Huynh-Feldt	10567.0	33.000	320.212			
	Lower-bound	10567.0	33.000	320.212			
Condition * Hand	Sphericity Assumed	41.656	1	41.656	.489	.489	.015
	Greenhouse-Geisser	41.656	1.000	41.656	.489	.489	.015
	Huynh-Feldt	41.656	1.000	41.656	.489	.489	.015
	Lower-bound	41.656	1.000	41.656	.489	.489	.015
Condition * Hand * Handedness_L1_R2	Sphericity Assumed	59.939	1	59.939	.703	.408	.021
	Greenhouse-Geisser	59.939	1.000	59.939	.703	.408	.021
	Huynh-Feldt	59.939	1.000	59.939	.703	.408	.021
	Lower-bound	59.939	1.000	59.939	.703	.408	.021
Condition * Hand * CueType_S1_W2	Sphericity Assumed	516.128	1	516.128	6.057	.019	.155
	Greenhouse-Geisser	516.128	1.000	516.128	6.057	.019	.155
	Huynh-Feldt	516.128	1.000	516.128	6.057	.019	.155
	Lower-bound	516.128	1.000	516.128	6.057	.019	.155
Condition * Hand * Handedness_L1_R2 * CueType_S1_W2	Sphericity Assumed	75.563	1	75.563	.887	.353	.026
	Greenhouse-Geisser	75.563	1.000	75.563	.887	.353	.026
	Huynh-Feldt	75.563	1.000	75.563	.887	.353	.026
	Lower-bound	75.563	1.000	75.563	.887	.353	.026
Error(Condition*Hand)	Sphericity Assumed	2811.87	33	85.208			
	Greenhouse-Geisser	2811.87	33.000	85.208			
	Huynh-Feldt	2811.87	33.000	85.208			
	Lower-bound	2811.87	33.000	85.208			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	66828.1	1	66828.1	107.733	.000	.766
Handedness_L1_R2	469.158	1	469.158	.756	.391	.022
CueType_S1_W2	110.716	1	110.716	.178	.675	.005
Handedness_L1_R2 * CueType_S1_W2	14.944	1	14.944	.024	.878	.001
Error	20470.4	33	620.314			

Significant main effect of hand

Estimates

Measure: MEASURE_1

Hand	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	17.271	1.972	13.259	21.283
2	26.067	3.054	19.854	32.281

Pairwise Comparisons

Measure: MEASURE_1

(I) Hand	(J) Hand	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-8.797*	3.000	.006	-14.900	-2.693
2	1	8.797*	3.000	.006	2.693	14.900

*Significant condition*hand*cuetype*

12. Handedness_L1_R2 * CueType_S1_W2 * Condition

Measure: MEASURE_1

Handedness_L1_R2	CueType_S1_W2	Condition	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	1	1	29.950	5.564	18.630	41.270
		2	19.431	4.319	10.645	28.217
	2	1	21.021	5.948	8.919	33.124
		2	23.536	4.617	14.143	32.929
2	1	1	19.886	4.745	10.232	29.540
		2	20.936	3.683	13.443	28.429
	2	1	21.764	4.745	12.110	31.418
		2	16.827	3.683	9.334	24.320

Pairwise Comparisons

Measure: MEASURE_1

Handedness_L1_R2	CueType_S1_W2	(I) RE_PRO	(J) RE_PRO	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	1	1	2	10.519*	4.656	.031	1.045	19.992
		2	1	-10.519*	4.656	.031	-19.992	-1.045
	2	1	2	-2.514	4.978	.617	-12.642	7.613
		2	1	2.514	4.978	.617	-7.613	12.642
2	1	1	2	-1.050	3.971	.793	-9.129	7.029
		2	1	1.050	3.971	.793	-7.029	9.129
	2	1	2	4.936	3.971	.223	-3.143	13.015
		2	1	-4.936	3.971	.223	-13.015	3.143